# “COMPARISON OF PULMONARY FUNCTION AND AUTONOMIC FUNCTION IN OBESE AND NON-OBESE INDIVIDUALS AGED BETWEEN 18 TO 25 YEARS”

**SANTOSH DEEMED TO BE UNIVERSITY**

(Established u/s 3 of the UGC Act 1956)

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Doctor of Medicine

In

Physiology

By

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# ABBREVATIONS

| | | |
|---|---|---|
| 1. | **AFT** | AUTONOMIC FUNCTION TEST |
| 2. | **BMI** | BODY MASS INDEX |
| 3. | **BP** | BLOOD PRESSURE |
| 4. | **CPT** | COLD PRESSOR TEST |
| 5. | **DBP** | DIASTOLIC BLOOD PRESSURE |
| 6. | **FVC** | FORCED VITAL CAPACITY |
| 7. | **$FEV_1$** | FORCED EXPIRATORY VOLUME PER 1 SECOND |
| 8. | **HR** | HEART RATE |
| 9. | **IHGT** | ISOMETRIC HAND GRIP TEST |
| 10. | **PFT** | PULMONARY FUNCTION TESTS |
| 11. | **SBP** | SYSTOLIC BLOOD PRESSURE |
| 12. | **V R** | VALSALVA RATIO |

# INTRODUCTION

**Obesity** is characterised by deposit of excessive amount of adipose tissue in the body, which can have negative effect on health.[1] Obesity is determined by using body mass index, which is

obtained by using individual's height and weight, with the help of a formula body mass index (BMI) =Weight(kg)/height$^2$ (meter$^2$). It is considered as a surrogate indicator to fatness [2]

For defining obesity, BMI categories differ according to age and gender in infants, children and adolescents.[3] For adults, individuals were categorized based on their Body Mass Index (BMI) into various weight classes. A BMI ≤ to 16.5 kg/m$^2$ is considered severely underweight, while BMI between 16.5kg/m$^2$ to 18.4 kg/m$^2$ is considered as underweight. Those with BMI ranging from 18.5 kg/m$^2$ to 24.9 kg/m$^2$ considered as normal weight. Individuals with BMI ranging from 25 kg/m$^2$ to 29.9 kg/m$^2$ are considered as overweight, individuals whose BMI of 30 kg/m$^2$ or greater indicated obesity, which further classified into three classes. Class I obesity whose BMI is between 30 kg/m$^2$ and 34.9 kg/m$^2$, obesity class II when BMI is in between 35 kg/m$^2$ to 39.9 kg/m$^2$, obesity class III when BMI is 40 kg /m$^2$or more than this. This class obesity is often termed as severe or morbid obesity. The categories help in assessing an individual's weight status.[4]

The prevalence of obesity is rising in India, with a rate of 4.76% among individuals age of 18 to 24years, 11.79% among 25- to 34-year-old.[5] Young adults, usually aged 18 to 25 and often termed 'emerging adults,' undergo a transition from adolescence to adulthood. During this period, they begin to live independently, pursue higher education or employment, form relationships, get married, and have children. This stage of life makes them more prone to weight gain.[6] Obesity is linked to numerous health problems, with the most prominent being cardiovascular, metabolic, orthopaedic, gastroenterological, pulmonary, and psychological disorders.[7]

Obesity is a significant and growing contributor to respiratory dysfunction, leading to a reduction in both static and dynamic pulmonary volumes. Individuals with obesity often experience decreased air entrance, exaggerated airway responsiveness, higher chances of

acquiring diseases like, pulmonary embolism, pulmonary hypertension, lung infections, obesity hypoventilation syndrome and obstructive sleep apnoea.[8]

The individuals who are obese are at higher risk of mortality, this may be due to blunted parasympathetic or impaired sympathetic activity which may lead to cardiovascular diseases.[9]

As obesity impacts both respiratory and autonomic nervous system which are important systems to maintain internal environment in homeostasis[10], so it very important to assess pulmonary and autonomic functions to prevent morbidity caused by obesity. The assessment of pulmonary and autonomic functions can be done by using system specific function tests, for pulmonary function it is pulmonary function tests and autonomic function tests for autonomic functions.

The pulmonary functions are a set of procedures used to evaluate the lung performance, measure lung volumes, capacities, flow rates and gas exchange. They can be performed by using spirometry and plethysmography.[11]

Most commonly used pulmonary function test is spirometry, the instrument used to assess is spirometer.[12] Spirometry evaluates the amount of air expelled at specific intervals during a forced exhale, following a full inspiration. The important parameters measured include the total exhaled volume, forced vital capacity (FVC), the volume of air exhaled in 1$^{st}$ sec (FEV $_1$), and their ratio $FEV_1/FVC$. The results of spirometry are usually presented on graph that illustrates volumes and their combinations, referred as lung capacities.[13]

Forced vital capacity refers to vital capacity refers to the maximum amount of air that can be e forcefully and rapidly exhaled after taking a deep breath.[14] Forced expiratory volume in 1 sec is the volume of air exhaled in first second of forced vital capacity. It serves as a key indicator of how effectively and rapidly the lungs can expel air.[15] The FEV1/FVC ratio, also known as the Tiffeneau-Pinelli index, is an important spirometric measure that shows the percentage of

a patient's vital capacity they exhale in the first second of forceful exhalation.[16] This ratio is widely used to diagnose and assess both obstructive and restrictive lung diseases, these three dynamic lung function parameters helps us to evaluate the functions of pulmonary system.

The autonomic function testing (AFT) refers to evaluation of integrity of sympathetic and parasympathetic division of autonomic nervous system. The tests used to test the autonomic reactivity of parasympathetic system, are heart rate response to deep breathing, Valsalva ratio, heart rate response to standing. To test sympathetic activity of sympathetic nervous system, tests like Beat-to-beat blood pressure recordings of Valsalva maneuvre, sustained handgrip test and cold pressor test.[17]

In literature there are many individual studies which focused the impact of obesity on pulmonary functions and autonomic functions respectively, but there is no individual study which comparing both pulmonary functions and autonomic functions among obese and non-obese individuals of age group 18 to 25 years. This study seeks to assess the effects of obesity on pulmonary and autonomic functions by assessing pulmonary function tests and autonomic function tests.

## AIM

To compare the pulmonary function and autonomic function between obese and non-obese individuals in the age group 18-25 years.

## OBJECTIVES

**Primary objective**: To compare pulmonary function and autonomic function between obese and non-obese individuals aged 18 to 25 years.

**Secondary objective**: To evaluate effect of obesity on individuals aged 18 to 25 years.

• A comparative study on pulmonary function tests between obese and non-obese young adult males, conducted by **Kumar, et al. (2024)** on medical students aged 18 to 24 years, revealed that obese individuals had significantly lower Forced Vital Capacity (FVC) and Forced Expiratory Volume in the first second (FEV1) compared to those with normal weight. The study also revealed there was an increasing trend of obesity as the age increases, the mean age of obesity in their age was 21.78±1.57.[18a]

• **Alqarni, A.A., et al. (2024)** conducted a study to investigate the prevalence of overweight and various obesity classes, as well as their impact on spirometry parameters, among individuals with unexplained dyspnoea in Saudi Arabia. The study findings showed negative co relation between BMI and FVC, FEV1, FEF 25–75 %, and PEF, and the study also found that all spirometry parameters FVC, FEV1, FEF 25–75%, and PEF were significantly lower in obese individuals with dyspnoea compared to those with normal weight.[19]

• **Jain,A., et al. (2023)** conducted a study to know the effects of obesity on pulmonary functions, on obese and non-obese individuals of age group 18-25 years. In their study they concluded that pulmonary functions such as peak expiratory flow rate and maximum voluntary ventilation decreased significantly ($P < 0.05$) in obese people when compared with non-obese people. forced vital capacity (FVC) and forced expiratory volume in 1s (FEV1) decreased in obese people when compared with non-obese people, but the results were not significant ($P > 0.05$). There was no change in FEV1/FVC%.[20]

• **Kanchanmala, et al. (2023)** conducted a study to compare forced vital capacity and forced expiratory volume in 1 sec among obese adults and non-obese adults, the study results showed there was statistically significant decrease in the value of FVC, FEV1 in obese male subjects compared to non-obese subjects.[21]

• **Mahajan, S., et al. (2020)** conducted a study to effects of obesity and spirometric ventilatory status in male Medical Students of age group 18 to 23 years old, the study results indicated a statistically significant decline in forced vital capacity (FVC) in obese males compared to their non-obese counterparts. When comparing the forced expiratory volume in the first second (FEV1) values between the two groups, significant differences were observed. However, the FEV1/FVC ratio, peak expiratory flow rate (PEFR), and forced mid-expiratory flow (FEF25-75%) showed no significant changes. On the other hand, maximum voluntary ventilation (MVV) demonstrated highly significant differences. The study concluded, obesity is associated with a decline in various respiratory functions.[22]

• **Sreehari, P., et al. (2020)** in their study; A Comparative Study of Pulmonary function tests in Obese and Non-Obese Young Male Students, which was studied among 90 students of age 19- to 24-year-old. The study concluded there is a reduction of FVC and FEV1/FVC these are due to restrictive effects of obesity on respiratory system.[23]

•**Shinde, et al. (2018**) conducted a study on 18–23-year-old medical students to assess the impairment of forced expiratory lung functions due to obesity. The study revealed that obese subjects presented a significant lower value of FEV1, FVC, FEV1 %, FEF 25-75%., PEFR as compared to nonobese subjects.[24]

• **Alam, M., et al. (2016)** conducted a study among to evaluate the relation of body weight with dynamic lung parameters in young healthy non-obese adult males in Eastern India, they concluded that as the weight of the individual increases the FVC and FEV1 increased.[25]

• The study by **Devershetty, J., et al. (2015)** examined the effect of obesity on pulmonary function tests in apparently healthy young women, conducted on sixty medical students from Osmania Medical College aged 18 to 25 years. The study found no significant differences in FEV1, FVC, and FEF25%–75% between obese and non-obese subjects. However, there were

significant differences in the FVC/FEV1 ratio and PEFR between the two groups. The study concluded that obesity affects respiratory functions even in younger individuals.[26]

• **Timmanna Koraddi, S., (2015)** conducted a comparative study on pulmonary functions in obese and non-obese students aged 18-25 years. The study found that obese individuals had reduced FVC, FEV1, FEV1/FVC ratio, PEFR, and MEP compared to their non-obese counterparts.[27]

•**Paralikar, S.J., et al. (2012)** conducted a study on assessment of pulmonary functions in obese adolescent boys of age group 12 to 17 years. The findings of their study showed decreased forced expiratory volume in the 1st second (FEV1)/forced vital capacity (FVC) and maximum voluntary ventilation (MVV).[28]

•A study done by **Vasudeva, R., et al. (2024)** showed that there in increase in sympathetic activity in overweight or obese individuals compared to normal people, the results were opposite to normal findings.[29]

• **Keshar, K., et al. (2023)** conducted a study to evaluate the impact of isometric handgrip exercise on cardiorespiratory responses in an Indian population with varying BMI levels, the study found that obese individuals had higher resting heart rates, systolic blood pressure, and diastolic blood pressure compared to non-obese individuals. After performing an isometric handgrip exercise, non-obese individuals experienced greater increases in heart rate, systolic blood pressure, and diastolic blood pressure than their obese counterparts.[30]

• **Holkunde, S., et al. (2023)** A study of autonomic function tests in obese subjects concluded that obesity is associated with both sympathetic and parasympathetic nervous system dysfunctions which may result in various cardiovascular complications.[31]

• **Sharma, R.K., et al. (2022)** conducted a study on effect of obesity on autonomic functions among healthy volunteers, the study concluded that the resting HR, SBP, and DBP were higher

in obese people. However, after applying the autonomic function tests, non-obese people respond better to these tests compared to obese people in the form of an increase in these parameters. Obesity is, thus, found to affect the autonomic function tests.[32]

• **Kaur, G., et al.** (2021) conducted a cross-sectional study to assess the relationship between autonomic dysfunction and obesity in adults using autonomic functions test as diagnostic tools. In this study 200 subjects were involved, grouped into obese and non-obese based on body mass index. The study results revealed that there was statistically significant decrease in both the sympathetic and parasympathetic activity in the obese adults.[33]

• **Mostarda, C., et al. (**2021) compared the autonomic modulation and sleep behaviour of eutrophic and overweight patients with chronic obstructive pulmonary disease (COPD). In their study they concluded that overweight COPD patients showed lower autonomic modulation and impaired sleep quality, latency, and efficiency as compared eutrophic subjects.[34]

• **Itagi, H., et al. (2020)** conducted a study to know the effect of obesity on cardiovascular responses to submaximal treadmill exercise in adult males of age 18 to 45 years old. The parameters they used were baseline heart rate, systolic blood pressure, diastolic blood pressure, mean arterial blood pressure and Qt and Qtc interval, in their study they concluded that baseline heart rate, blood pressure and mean arterial blood pressure was higher in obese individuals.[35]

• **Mahapatra. A. K,** (2019) study, Comparison of Autonomic Function in Obese and Non-Obese Medical Students findings suggest that in person with obesity with higher BMI are at high risk for autonomic dysfunction as compared to person with normal weight.[36]

• **Sugantha, M.J, et al. (2019)** study concluded that obese individual has impaired responses to autonomic stress tests and have high levels of baseline sympathetic activity, even at rest the obese people having increased heart rate when compared to normal individuals.[37]

• **Rafiq.N, et al. (2019)** study revealed an altered autonomic function in the form of impaired sympathetic activity with no parasympathetic modulation in obese young adults. The study was done among 150 healthy young students of aged 18–25 years, who were grouped on basis of body mass index, and autonomic function tests done were Lying to Standing test, Valsalva manoeuvre, Hand grip test (HGT) and Cold pressor test.[38]

• **Sinha, H.M.P, et al. (2018)** conducted a study on 300 students both males and females of age group 18 to 25 to determine sympathetic and parasympathetic responses to stress using hand-grip dynamometer and sinus arrhythmia test. In this study they concluded that obesity potentially alters autonomic balance with increased sympathetic and reduced parasympathetic activity.[39]

• **Goyal, K., et al, (2018)** In their study, blood pressure response to sustained handgrip exercise showed statistically highly significant decrease in obese subjects as compared to non-obese subjects, it concluded that obesity is associated with sympathetic nervous system dysfunction.[40]

• **Elayaperumal,P., et al.(2018)** conducted a study to estimate the impact of obesity on autonomic functions in female, their study they used non-invasive autonomic functions Resting heart rate, heart rate response to Valsalva maneuvre, heart rate variation during deep breathing (Expiration/Inspiration ratio), 30:15 ratio (Heart rate response to immediate standing),S:L ratio (standing to lying ratio),blood pressure response to standing, blood pressure response to sustained handgrip concluded that obesity did not had any effect on the autonomic functions.[41]

• **Bhattacharjee, A., et al. (2018)** conducted a study to evaluate the effect of obesity on pulmonary functions of young adults from Malaysia university. The results of that study showed that there is increased FVC, FEV1 and decreased FEV 1 /FVC obese individuals.[42]

• **Das, D., et al. (2017)** conducted a study on 18–25-year-old medical students to evaluate cardiac autonomic function among overweight males, in their study parasympathetic test

parameters of study and control groups were not statistically significant. In sympathetic test, that is isometric hand grip test the results were significant. In conclusion the study showed overweight young male have altered sympathetic activity but parasympathetic activity there was no significant change compared to normal young males.[43]

• **Poobalan, A., et al. (2016)** a systemic overview study done on obesity among young adults in developing countries, the prevalence rate among UK, USA and developing countries among young adults of age 18 to 23 was 22 to 35% among India and other countries it was higher than these numbers. The study also revealed that BMI waist circumference, waist and hip ratio increases from age of 15–19-year-old to 20 to 29 years.[44]

• **Chowdhury, S.G., et al. (2016)** conducted a study to know the effect of BMI on dynamic lung functions on young adults, the results showed obese group presented a significant lower value of forced vital capacity and forced expiratory volume per 1sec compared to non-obese group.[45]

• **Ali, A., et al, (2016)** conducted a study to examine any added effects of obesity on cardiac autonomic dysfunction in hypertensive patients, consisted of non-obese hypertensive subjects and obese (BMI≥30kg/m2) hypertensive subjects. Cardiac autonomic function was assessed using four tests – Heart rate response to immediate standing (30:15 ratio), standing to lying ratio (S/L ratio), Blood pressure response to immediate standing and Cold Pressor Test (CPT). The study concluded that there were no significant differences for autonomic function tests between obese and non-obese hypertensive subjects ($p > 0.05$).[46]

• **Rossi, R.C., et al. (2015)** conducted a study to evaluate the impact of obesity on autonomic modulation, heart rate and blood pressure in obese young people, which was done among 90 young adults. The study has concluded that obese individuals have high baseline heart rate, blood pressure when compared to normal weight individuals.[47]

• **Irani FB, et al. (2014)** conducted a study on 18–25-year-old medical students who were grouped into obese and non-obese based on BMI, the autonomic function test like hand grip and cold pressor test are performed on these individuals. The study concluded that there is derangement of autonomic and cardiac functions.[48]

• **Garg, R., et al. (2013)** conducted a study on autonomic functions in obese people of age group 21 to 40 years, the results of this study showed that the heart rate response to standing (30:15 ratio), the standing-to-lying (S:L) ratio, the Valsalva ratio, heart rate response to deep breathing, the Isometric Handgrip Exercise Test, and the Cold Pressor Test were all significantly lower in obese individuals compared to control subjects. These findings suggest that latent autonomic neuropathy may be present in otherwise healthy obese individuals.[49]

• **Grewal, S., et al. (2011)** conducted a study on 100 volunteers, in which 50 members were obese and other 50 members were non obese. In this study they evaluated functioning of autonomic nervous system by using six non-invasive tests, among these four are parasympathetic control tests and other two are sympathetic control tests. The tests showed dysfunction of autonomic functions.[50]

• **Kumar, S.AV., et al, (2007**) done a comparative study of sympathetic cardiovascular tests in obese and non-obese adults. The cardiovascular sympathetic function tests have been conducted in 30 cases of obese adults and 30 controls i.e., non-obese adults aged between 30-50 years, including both sexes. Cases showed statistically significant decreased response of systolic and diastolic blood pressure to cold pressor and to sustained handgrip. The responses in cases were significantly correlated to Body Mass Index (BMI), signifying that autonomic dysfunction occurs in Obesity.[51]

• **Cloak, et al. (2002)** conducted a study to examine autonomic nervous system functions in obese people by non-invasive methods, like orthostatic test, isometric exercise test, Valsalva

ratio test, 30/15 ratio test, heart rate change test by deep respiration. In their study it was concluded that there is hypofunctional sympathetic autonomic nervous system dysfunction in obese subjects.[52]

• Study conducted by **Valensi, P., et al. (1995)** among 121 obese people concluded that cardiac autonomic dysfunction frequents in the non-diabetic obese subjects.[53]

# METHODS AND MATERIALS

**STUDY DESIGN**: Comparative Observational Study

**STUDY CONDUCTED AT**: Study conducted at Department of physiology, Santosh Medical College, Ghaziabad.

**SAMPLE SIZE**: 100 Subjects

**SAMPLE SIZE CALCULATION**

The study done by **Nitish Kumar, et al (2024)** is taken as a reference for calculation of sample size. The parameter used is Forced vital capacity of pulmonary function test. The Mean and Standard deviation of Forced Vital Capacity is taken into consideration.[18b]

| Parameter | Obese group | Non-obese group |
|---|---|---|
| **FVC** | **Mean ± SD 3.12±0.60** | **Mean± SD 3.54±0.87** |

Table No.1

The following simple formula would be used for calculating the adequate sample size

$$n = \left(Z_{1-\alpha/2} + Z_{1-\beta}\right)^2 \frac{(s_1^2 + s_2^2)}{(\overline{X_1} - \overline{X_2})^2}$$

- Where n is the sample size,
- $Z_{1-\frac{\alpha}{2}}$ = two-sided Z value (1.96 at 95% level of significance)
- $Z_{1-\beta}$ = power at 80%
- $S_1$ = standard deviation of group 1
- $S_2$ = standard deviation of group 2

- $\overline{X_1}$ = mean of group 1
- $\overline{X_2}$ = mean of group 2

**INCLUSION CRITERIA**

- Individuals aged 18 to 25 years
- Non-obese criteria: BMI ≥ 18.9 to 29.9 kg/$m^2$
- Obesity criteria**:** BMI ≥ 30 kg/$m^2$

**EXCLUSION CRITERIA**

- Individuals with chronic respiratory and cardiovascular diseases
- Individuals those on medication affecting pulmonary or autonomic functions.
- Individuals who smoke, consume caffeine, alcohol.

**APPARATUS USED**

1. KRUPS analog Weighing Machine to measure weight
2. Stadiometer to measure height
3. Clarity Medical Portable Spirometer (Clarity Spiro Tech CMSP-01)
4. INCO Handheld Hand Grip Dynamometer
5. Mercury Thermometer
6. Manual Mercury Sphygmomanometer to record blood pressure.
7. Stethoscope

Figure.No.1: Weighing Machine

Figure.No.2: Stadiometer

Figure.No.3: Clarity Portable Spirometer

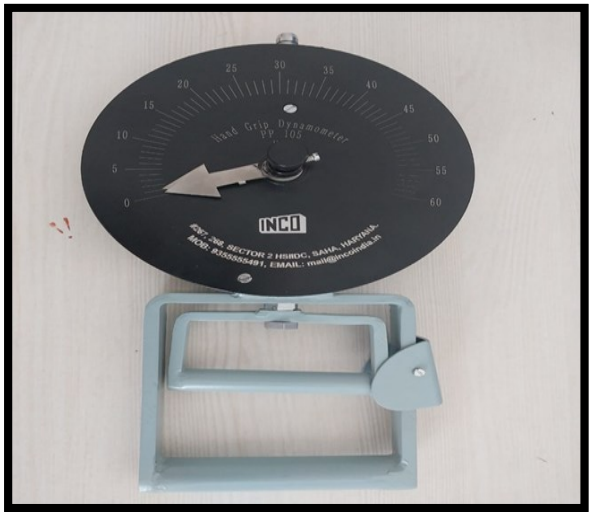


Figure No.4: INCO Handheld Dynamometer.

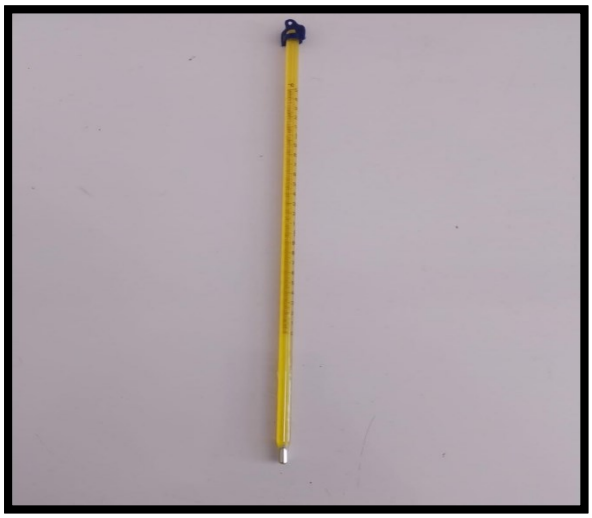

Figure No.5: Mercury Thermometer

Figure.No.6: Manual Mercury Sphygmomanometer

Figure No.7: Stethoscope

**STUDY DESIGN**

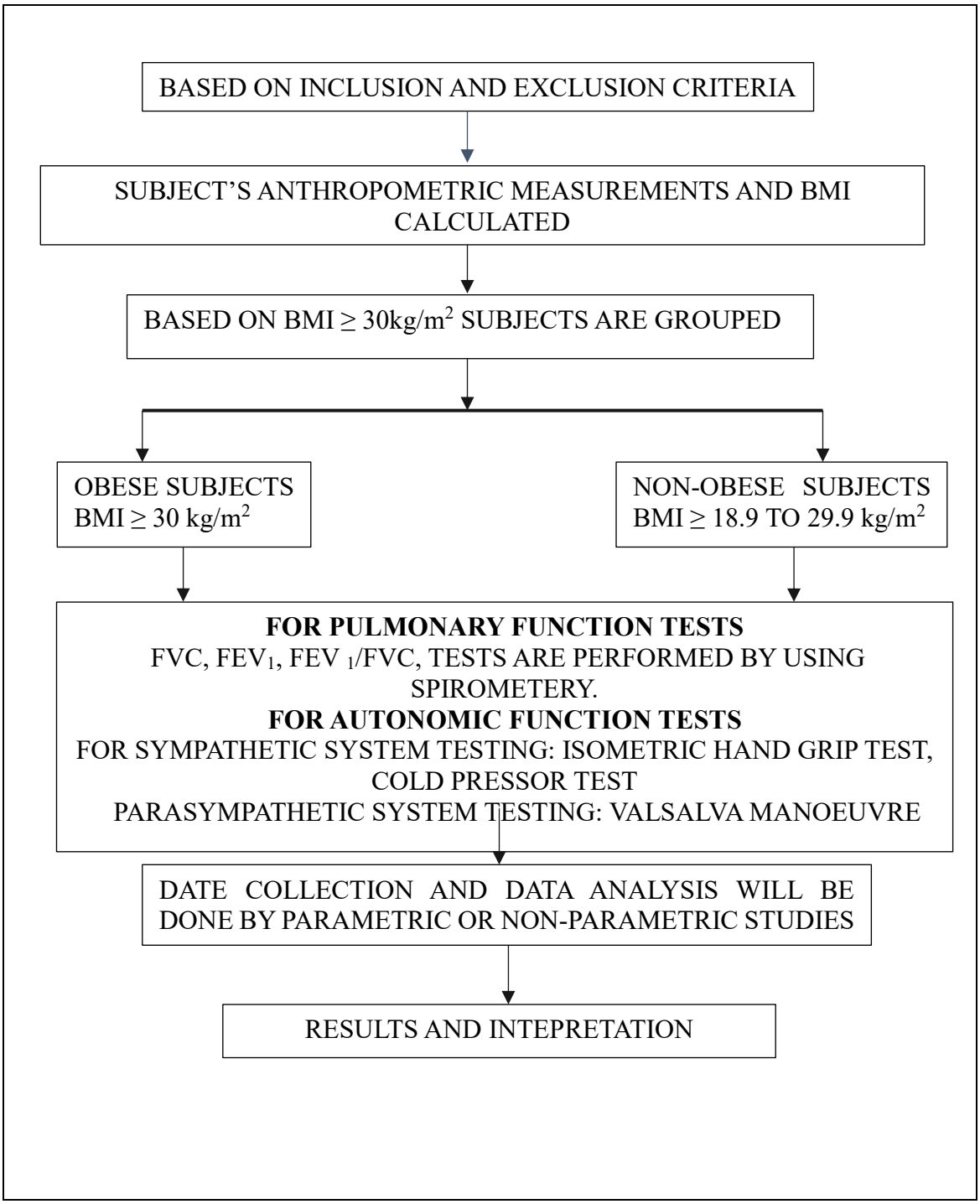
BASED ON INCLUSION AND EXCLUSION CRITERIA
SUBJECT'S ANTHROPOMETRIC MEASUREMENTS AND BMI CALCULATED
BASED ON BMI ≥ 30kg/m2 SUBJECTS ARE GROUPED
OBESE SUBJECTS BMI ≥ 30 kg/m2
NON-OBESE SUBJECTS BMI ≥ 18.9 TO 29.9 kg/m2
FOR PULMONARY FUNCTION TESTS
FVC, FEV1, FEV 1/FVC, TESTS ARE PERFORMED BY USING SPIROMETERY.
FOR AUTONOMIC FUNCTION TESTS
FOR SYMPATHETIC SYSTEM TESTING: ISOMETRIC HAND GRIP TEST, COLD PRESSOR TEST
PARASYMPATHETIC SYSTEM TESTING: VALSALVA MANOEUVRE
DATE COLLECTION AND DATA ANALYSIS WILL BE DONE BY PARAMETRIC OR NON-PARAMETRIC STUDIES
RESULTS AND INTEPRETATION

Figure No.8: Study Design

## METHODOLOGY

In alignment with the study's objectives, the data collection was designed after reviewing relevant literature.

The data collection schedule is typically organized into four sections.

Section I: obtaining subjects history and informed consent

Section II: general physical examination and anthropometric parameters measurements.

Section III: assessment of pulmonary functions through pulmonary function tests.

Section IV: assessment of autonomic functions through autonomic function tests.

Section I: The subjects personal, present, past and medical history is taken, then they were provided with the information of the study, including its objectives and procedures they would undergo. This helped alleviate any anxiety and ensured they were calm. Following this, informed consent from subject is obtained.

Section II: a general physical examination and anthropometric parameters measurements were performed on the subjects.

The baseline heart rate, systolic blood pressure, and diastolic blood pressure were recorded.

The subjects height and weight were measured, and basis of these parameters body mass index (BMI) was calculated using the formula BMI = weight (kg)/height ($m^2$). The subjects were categorized into obese and non-obese groups based on their BMI values.

The baseline heart rate, systolic blood pressure, and diastolic blood pressure were recorded. The subject's height and weight were measured, and from these, the BMI of everyone was calculated using the formula: BMI = Weight (kg) / Height ($m^2$). The participants were categorized into obese and non-obese groups based on their BMI values. A BMI of ≥30 kg/$m^2$

was considered obese, while a BMI ranging from ≥18.9 to 29.9 kg/m² was classified as non-obese.

Section III: Assessment of various pulmonary function tests with the help of spirometry. Pulmonary function tests forced vital capacity (FVC), forced expiratory volume in 1 sec ($FEV_1$), and $FEV_1$/FVC are measured.

Spirometry performing procedure:

The test was performed with Clarity medical portable spirometer model; Clarity Spiro Tech CMSP-01, it is calibrated with A 3-liter calibration syringe before starting of the procedure. The test been performed on subjects without any bronchodilation medication prior to procedure.

During the test, the subjects were directed to sit with an upright posture, ensuring their legs were uncrossed and feet were flat on the ground. To prevent nasal breathing, a nose clip was applied to block the nostrils. The subjects were then asked to breathe in completely and rapidly, pausing for less than one second. Next, were asked to place the mouthpiece in their mouth, sealing their lips tightly around the mouthpiece to form a proper seal. Then, the subjects exhaled air forcefully and rapidly as possible until their lungs were completely empty or until they were unable to exhale any more. After this, the subject inhaled deeply and rapidly again and removed the mouthpiece at the end of the procedure.[54]

In this test we are looking for following parameters

- Forced vital capacity (FVC)
- Forced expiratory volume per 1 sec ($FEV_{1)}$
- Forced expiratory volume per 1sec/ Forced vital capacity ($FEV_1$/FVC).

Section IV: Assessment of the various autonomic function tests.

After assessing pulmonary function tests of subjects, next the autonomic functions were assessed by autonomic function tests to assess the integrity of autonomic nervous system in both groups of the study. The autonomic function tests performed were in this order: Valsalva ratio (VR) to assess Parasympathetic system, Isometric handgrip test (IHGT), and Cold pressor test (CPT) are used to assess Sympathetic system.

The baseline parameters like heart rate, blood pressure is measured in all subjects.

For Assessing Parasympathetic Function

Heart rate response to Valsalva maneuvre: The subjects were asked to sit on a chair with their nostrils closed using a nose clip. Then, a mouthpiece was placed into their mouths, which was connected to a digital mercury manometer. They were instructed to breathe forcefully into the manometer and maintain an expiratory pressure of 40 mm of Hg for 15 seconds. The Valsalva ratio was calculated from the maximal heart rate generated during maneuver, divided by the lowest heart rate following procedure. Normal: ≥ 1.21Abnormal ≤1.20 [55]

For Assessing Sympathetic Function

Blood pressure response to Isometric handgrip test: The Isometric Handgrip Test was conducted to assess blood pressure response to isometric handgrip, First the subjects baseline blood pressure was recorded, then they were asked to perform maximum handgrip with handheld dynamometer three times with 3 to 4 seconds gap between each attempt, using their dominant hand. The maximum voluntary contraction was calculated, Afterward, the subjects were instructed to maintain a handgrip at 30% of maximum voluntary contraction for 3 minutes. The blood pressure was measured immediately after the release of the grip and the

difference in diastolic blood pressure before and after the procedure calculated. Normal ≥16mmHg, Borderline: 11-15 mmHg, Abnormal <10mmHg[56]

Cold pressor test (CPT): The baseline blood pressure was recorded after the subjects were rested for 10minutes. The test was performed in quiet room with a temperature $23C^0$ and in a comfortable environment, at same time every day to avoid diurnal variation. One of the subjects hands was immersed in cold water at a temperature of 1-4 $^0$ C up to the wrist joint. Then the blood pressure is recorded in the contralateral arm. After removing the hand from the cold water, blood pressure was recorded every minute until it returned to baseline level. A rise in diastolic blood pressure greater than 15mm of Hg was taken as normal and less than 15 mm of Hg considered as abnormal.[57]

Performing Anthropometric Measurements

Figure.No.9: Measurement of height of subject

Figure No.10: Measurement of weight of subject

Figure.No.11: Subject performing spirometry

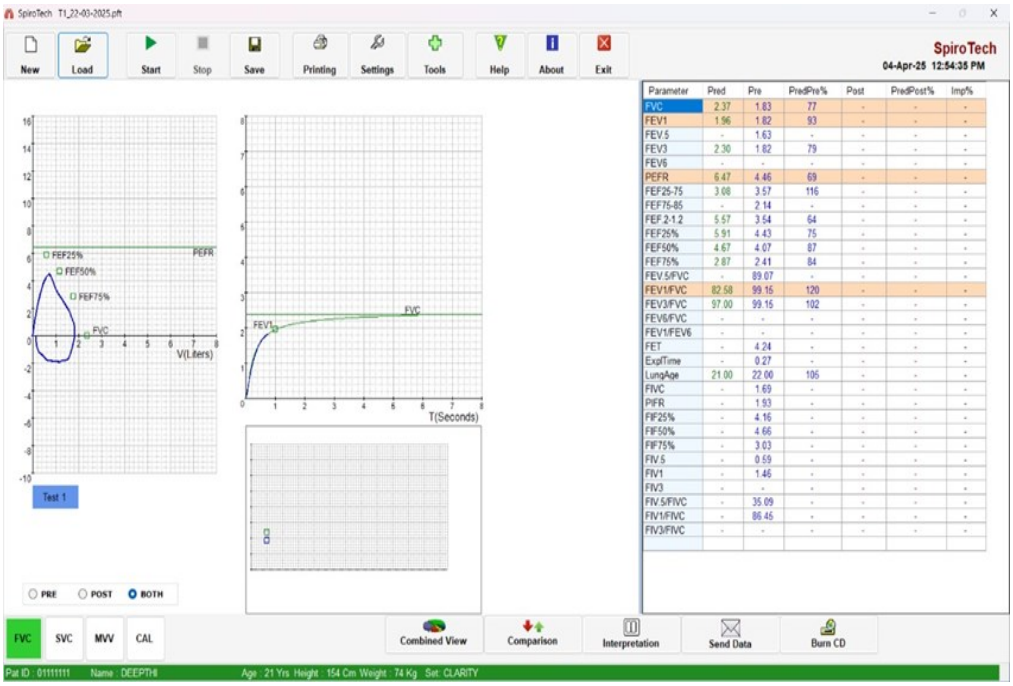


Figure No.12: Graph and result of spirometry of a subject

## STATISTICAL ANALYSIS

All the data was presented as Mean (Mean ± SD) and standard deviation. To study the significance of difference in parameters between obese and non -obese groups, applied the student's unpaired 't' test and for correlation of parameters Pearson coefficient was applied. The results were expressed as statistically non-significant if $P > 0.05$, as significant if $P < 0.05$, as highly statistically significant if $P < 0.001$.

## OBSERVATIONS AND RESULTS

**Age:**

- The mean age of obese individuals (20.24 ± 1.238) is significantly higher than that of non-obese individuals (19.64 ± 1.005).
- The t-value (2.660) and p-value (.009) indicate a statistically significant difference ($p < 0.05$), suggesting that obesity is associated with a slightly higher age in this sample.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P-Value |
|---|---|---|---|---|
| Obese | 20.24±1.238 | 0.175 | 2.660 | 0.009 |
| Non-obese | 19.64±1.005 | 0.142 | | |

Table No.2: MEAN±SD of age for obese and non- obese.

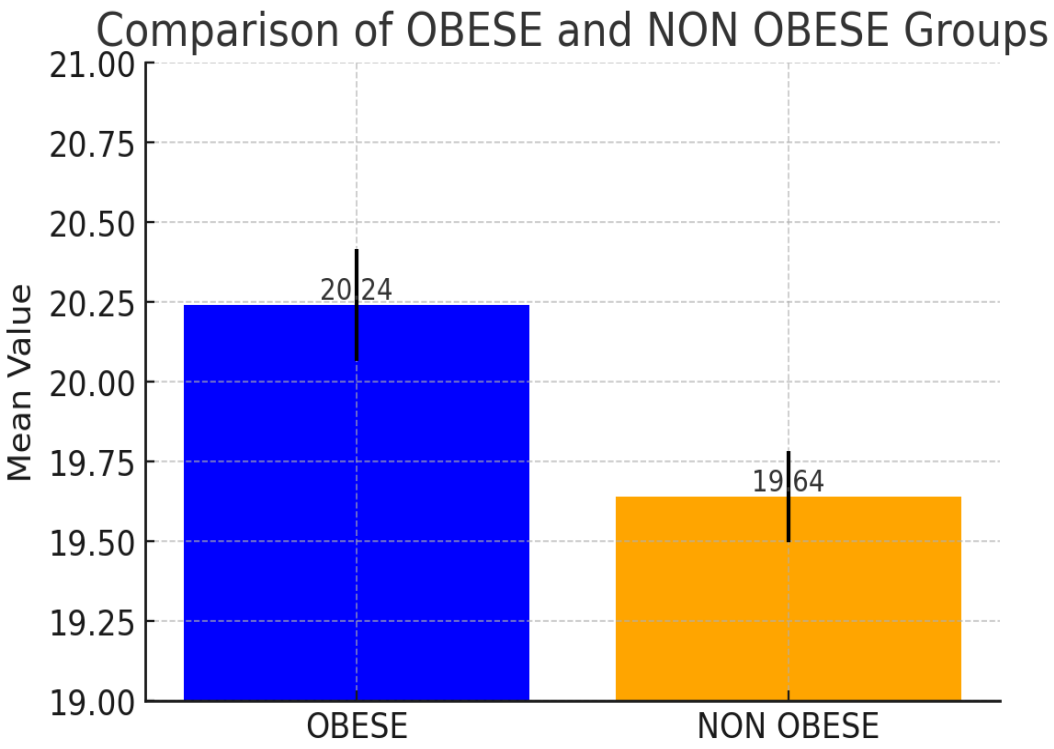


Figure No.13: Comparison of obese and non-obese with age

## Age frequency in male and female subjects

| Age | Male | Female | Total | M % | F% |
|---|---|---|---|---|---|
| 18 | 6 | 6 | 12 | 50.0% | 50.0% |
| 19 | 10 | 14 | 24 | 41.7% | 58.3% |
| 20 | 15 | 15 | 30 | 50.0% | 50.0% |
| 21 | 16 | 12 | 28 | 57.1% | 42.9% |
| 22 | 1 | 3 | 4 | 24.0% | 75.0% |
| 23 | 2 | 0 | 2 | 100% | 0.0% |

Table No.3: Age frequency in males and females

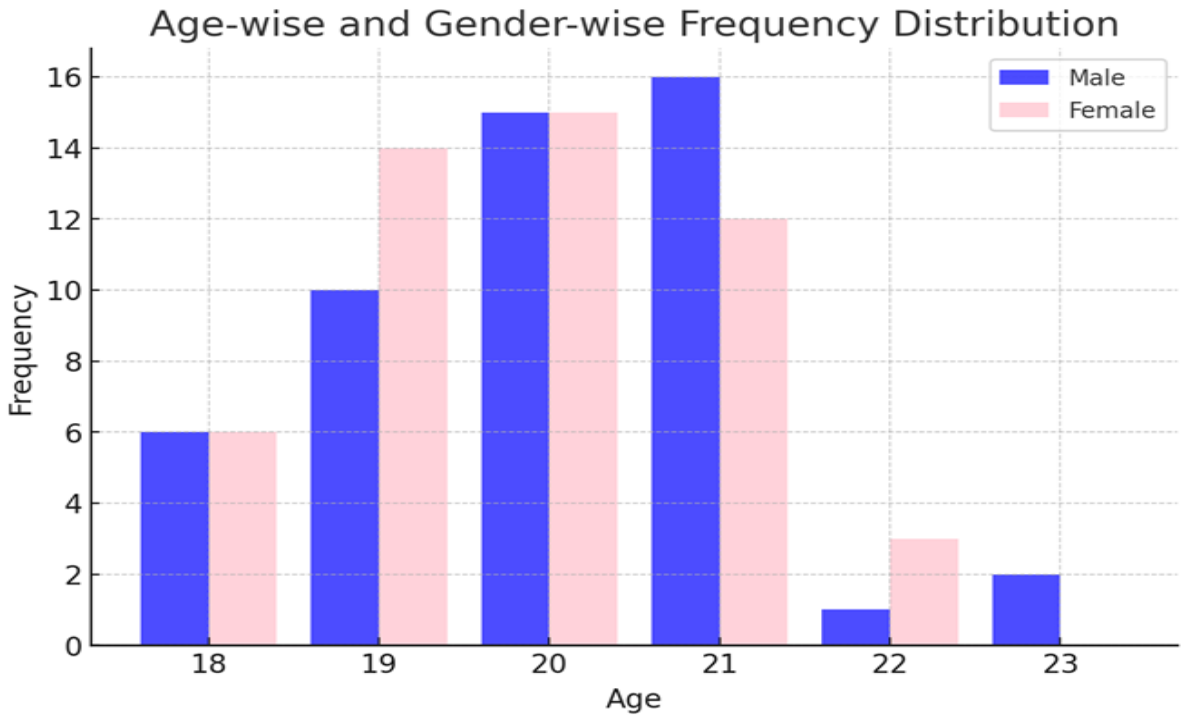


Figure No.14: Age and gender wise frequency distribution

**BMI (Body Mass Index):**

- Obese individuals have a significantly higher BMI (30.81 ± 2.49) compared to non-obese individuals (22.75 ± 2.17).
- The high t-value (17.214) and extremely small p-value (.000) confirm a highly significant difference.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 30.81±2.49 | 0.35256 | 17.214 | 0.000 |
| Non-obese | 22.75±2.17 | 0.30808 | | |

Table No.4**: MEAN±SD of BMI for obese and non-obese**

Figure No.15: Mean comparison of BMI with obese and non-obese

**FVC (Forced Vital Capacity):**

- Obese individuals have a lower FVC (3.01 ± 0.45) compared to non-obese individuals (3.27 ± 0.36).
- The t-value (-3.240) and p-value (.002) indicate a statistically significant reduction in lung capacity in obese individuals.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 3.0106±0.44893 | 0.06349 | -3.240 | 0.002 |
| Non-obese | 3.2748±0.36178 | 0.05116 | | |

Table No.5: MEAN±SD of FVC for obese and non-obese

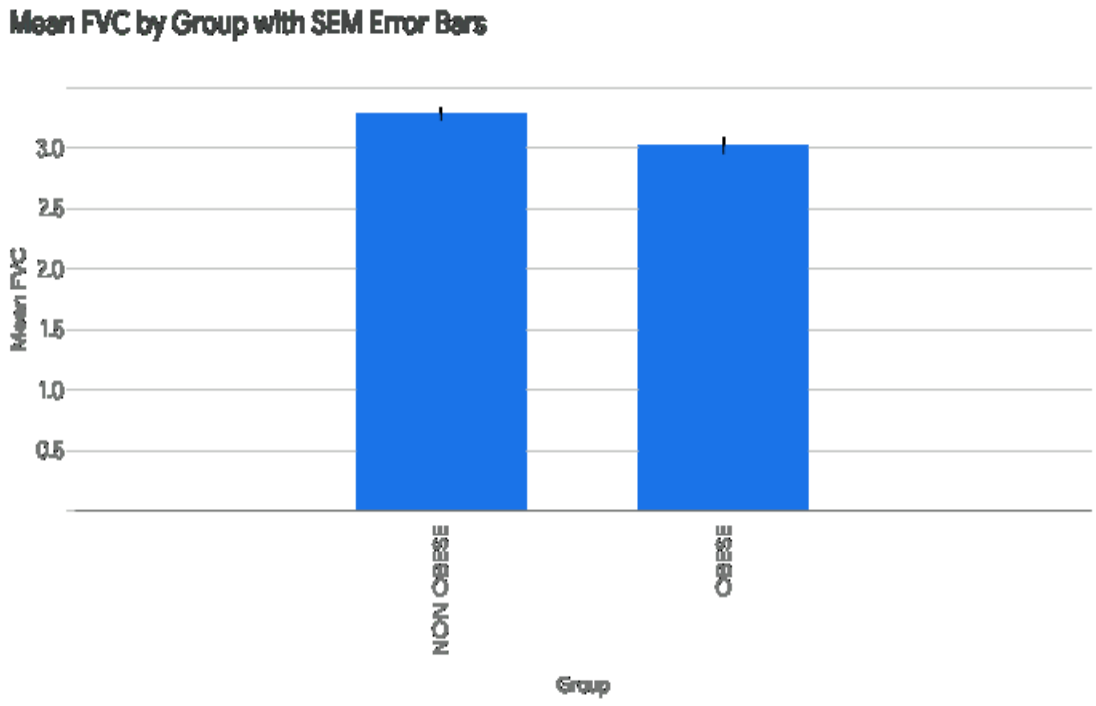


Figure No.16: Mean comparison of FVC with obese and non-obese

**FEV1 (Forced Expiratory Volume in 1 second)**

- Obese individuals have a slightly lower FEV1 (2.63 ± 0.49) compared to non-obese individuals (2.79 ± 0.38).
- The t-value (-1.796) and p-value (.076) suggest no significant difference ($p > 0.05$), implying that obesity does not have a major impact on FEV1 in this sample.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 2.6358±0.49893 | 0.07002 | -1.796 | 0.076 |
| Non-obese | 2.7942±0.37178 | 0.05366 | | |

Table No.6: MEAN±SD of $FEV_1$ for obese and non-obese

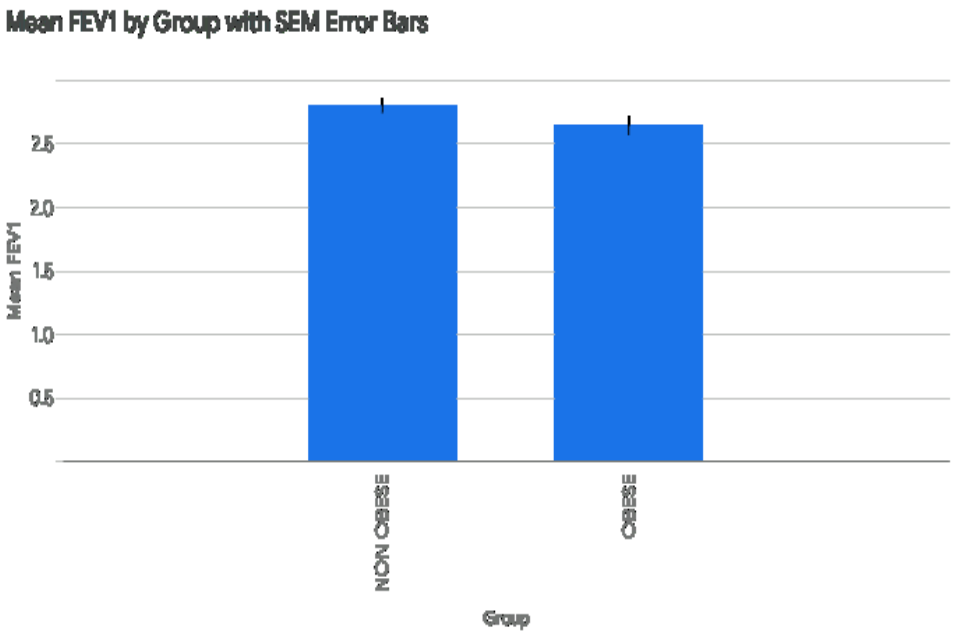


Figure No.17: Mean comparison of FEV1 with obese and non-obese

**FEV1/FVC Ratio**

The ratio is slightly higher in obese individuals (87.90 ± 12.52) than in non-obese individuals (85.41 ± 7.42).

The t-value (1.208) and p-value (.231) indicate no statistically significant difference, suggesting restrictive pattern of disease

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 87.8996±12.52659 | 1.77153 | 1.208 | 0.231 |
| Non-obese | 85.4114±7.442577 | 1.05016 | | |

Table No.7: MEAN±SD of FEV1/FVC for obese and non-obese

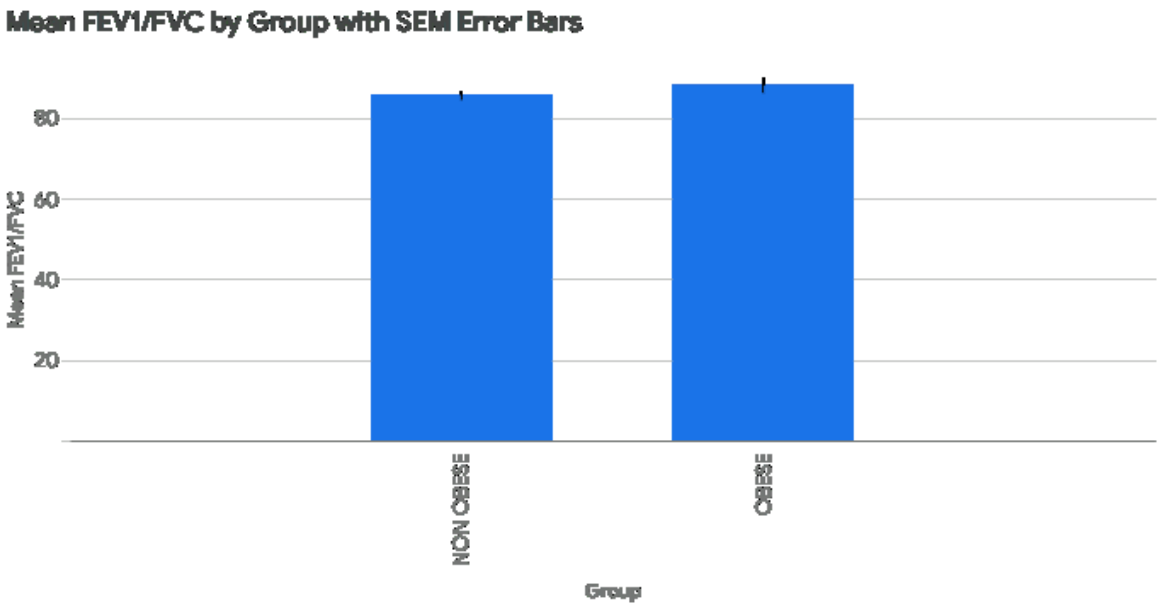


Figure No.18: Mean comparison of FEV1/FVC with obese and non-obese

**Baseline Heart Rate (HR):**

Obese individuals have a baseline HR of 82.40 ± 8.17, whereas non-obese individuals have 75.12 ± 6.246.

The t-value (7.380) and p-value (0.0001) indicate there is highly significant difference in the baseline heart rate between obese and non-obese subjects.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 82.40±8.172 | 1.156 | 7.380 | 0.0001 |
| Non-obese | 75.12±6.246 | 1.296 | | |

Table No.8: MEAN±SD of baseline heart rate for obese and non-obese.

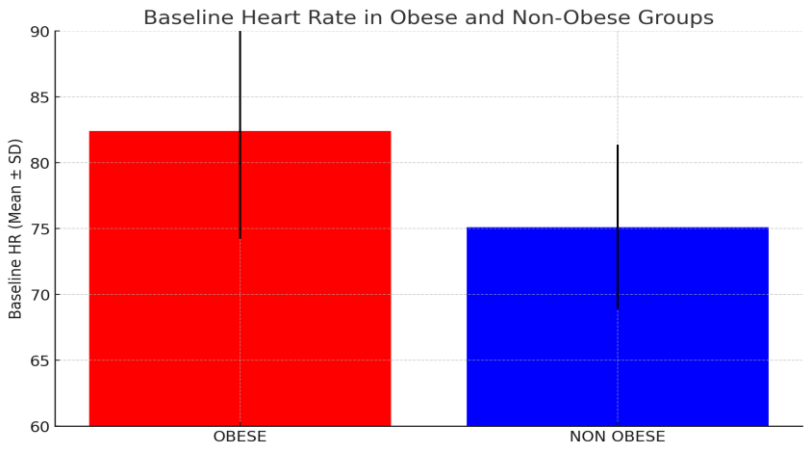


Figure No.19: Mean comparison of baseline heart rate with obese and non-obese

**Baseline Systolic Blood Pressure (SBP)**

- Obese individuals have significantly higher SBP (106.80 ± 8.79) compared to non-obese individuals (99.48 ± 8.42).
- The t-value (4.254) and p-value (.000) confirm a highly significant difference, indicating that obesity is associated with higher systolic blood pressure.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 106.80±8.788 | 1.243 | 4.254 | 0.000 |
| Non-obese | 99.48±8.146 | 1.190 | | |

Table No.9: MEAN±SD of baseline Systolic blood pressure for obese and non-obese.

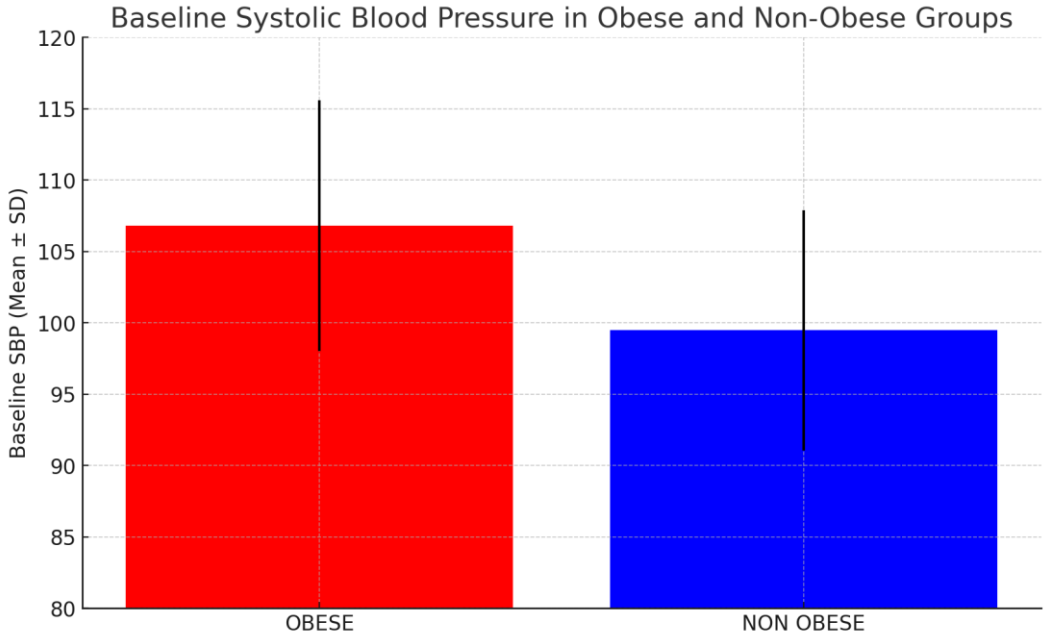


Figure No.20: Mean comparison of baseline SBP with obese and non-obese

**Baseline Diastolic Blood Pressure (DBP)**

- Obese individuals have significantly higher DBP (70.00 ± 4.57) than non-obese individuals (67.28 ± 3.98).
- The t-value (3.175) and p-value (.002) indicate a significant difference, suggesting that obesity is linked to increased diastolic pressure.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 70.00±4.571 | 0.646 | 3.175 | 0.002 |
| Non-obese | 67.28±3.975 | 0.562 | | |

Table No.10: MEAN±SD of baseline diastolic blood pressure for obese and non-obese.

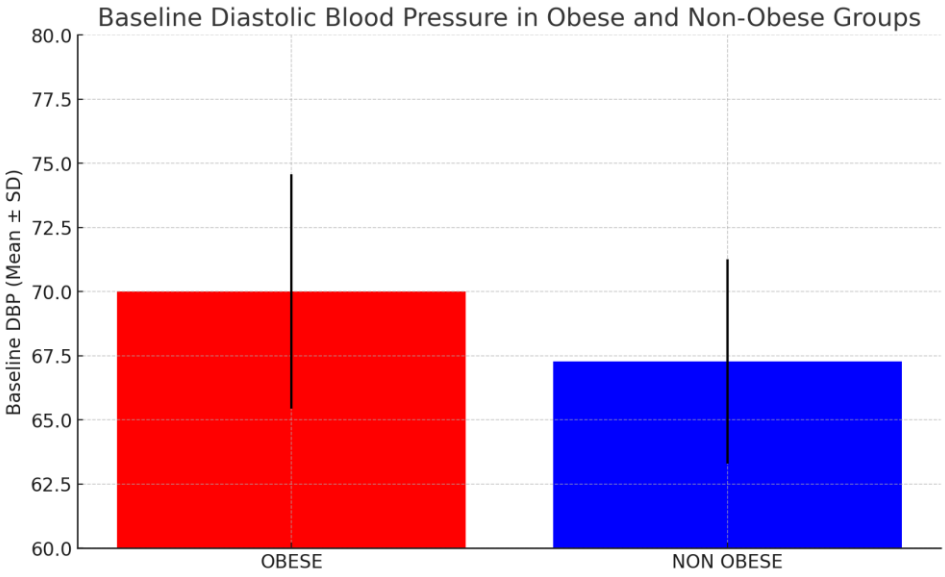


Figure No.21: Mean comparison of baseline DBP with obese and non-obese

**Valsalva Ratio:**

- The ratio is lower in obese individuals (1.56 ± 0.16) than in non-obese individuals (1.83 ± 0.10).
- The t-value (-10.172) and p-value (.000) indicate a highly significant difference, suggesting that autonomic function (as measured by the Valsalva ratio) is impaired in obese individuals.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 1.5618±0.15911 | 0.02250 | -10.172 | 0.000 |
| Non-obese | 1.8358±0.10471 | 0.01481 | | |

Table No.11: MEAN±SD of Valsalva ratio for obese and non-obese

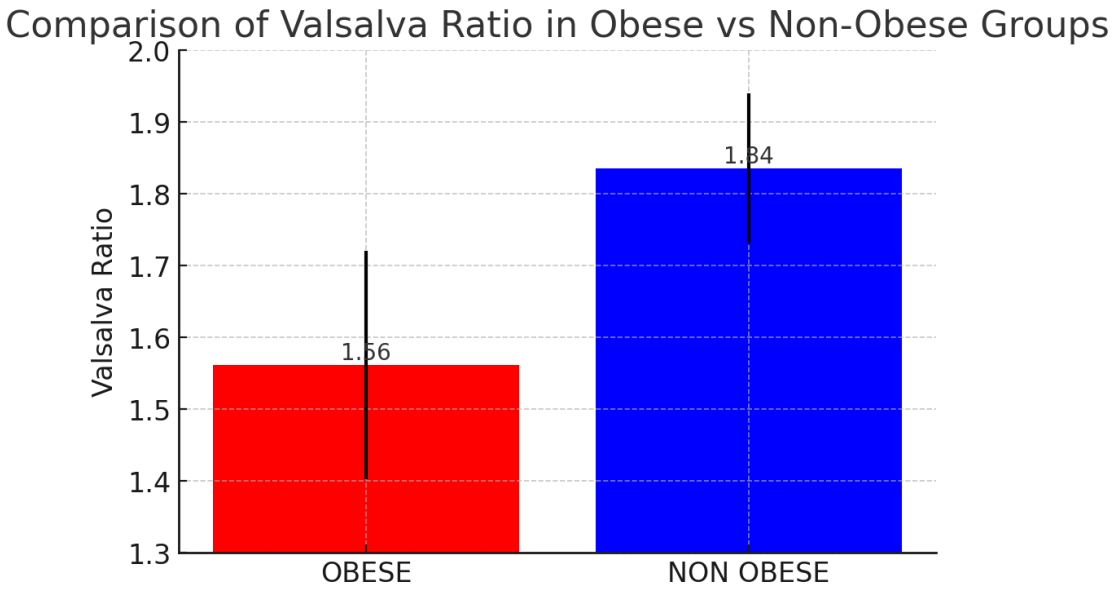


Figure No.22: Mean comparison of Valsalva ratio with obese and non-obese

**Rise in DBP during Isometric Handgrip Test (IHGT):**

- The increase in DBP is lower in obese individuals (15.52 ± 2.00) than in non-obese individuals (17.60 ± 1.46).
- The t-value (-5.939) and p-value (.000) indicate a highly significant difference, showing that obesity is linked to reduced blood pressure response to isometric exercise.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 15.52±2.002 | 0.283 | -5.939 | 0.000 |
| Non-obese | 17.60±1.457 | 0.206 | | |

Table No.12: MEAN±SD of rise in diastolic blood pressure in IHGT for obese and non-obese

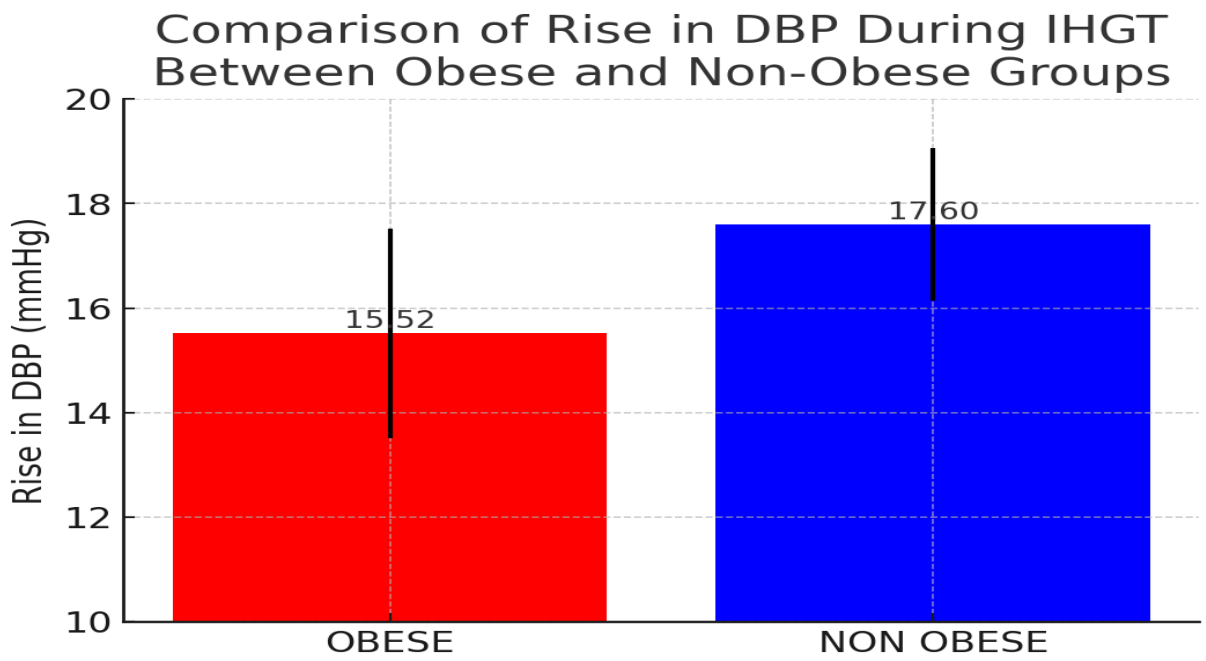


Figure No.23: Mean comparison of DBP rise in IHGT with obese and non-obese

**Rise in DBP during Cold Pressor Test (CPT):**

Obese individuals show a lower rise in DBP (11.16 ± 1.57) compared to non-obese individuals (14.56 ± 1.57).

The t-value (-10.840) and p-value (.000) indicate a highly significant difference, suggesting that obese individuals have a reduced sympathetic response to cold stress.

| Type | Mean±SD | Std.Error Mean | t-Statistics | P Value |
|---|---|---|---|---|
| Obese | 11.16±1.570 | 0.222 | -10.840 | 0.000 |
| Non-obese | 14.56±1.567 | 0.222 | | |

Table No.13: MEAN±SD of rise in diastolic blood pressure in CPT for obese and non-obese

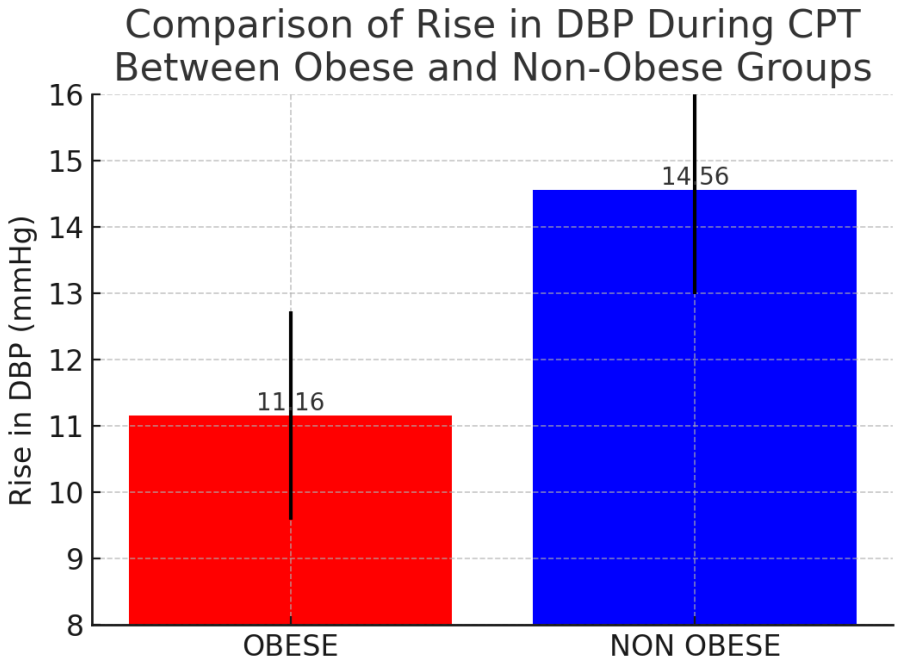


Figure No.24: Mean comparison of rise in DBP in CPT with obese and non-obese

| Parameter | Type | Mean | Std. Deviation | Std. Error Mean | t - Statistics | P Value |
|---|---|---|---|---|---|---|
| Age | Obese | 20.24 | 1.238 | .175 | 2.660 | .009 |
| | Non-obese | 19.64 | 1.005 | .142 | | |
| BMI | Obese | 30.8134 | 2.49295 | .35256 | 17.214 | .000 |
| | Non-obese | 22.7540 | 2.17849 | .30808 | | |
| FVC | Obese | 3.0106 | .44893 | .06349 | -3.240 | .002 |
| | Non-obese | 3.2748 | .36178 | .05116 | | |
| FEV 1 | Obese | 2.6358 | .49508 | .07002 | -1.796 | .076 |
| | Non-obese | 2.7942 | .37947 | .05366 | | |
| $FEV_1/FVC$ | Obese | 87.8996 | 12.52659 | 1.77153 | 1.208 | .231 |
| | Non-obese | 85.4114 | 7.42577 | 1.05016 | | |
| Baseline Heart rate | Obese | 82.40 | 8.172 | 1.156 | 7.380 | 0.001 |
| | Non-obese | 75.12 | 6.246 | 1.296 | | |
| Baseline SBP | Obese | 106.80 | 8.788 | 1.243 | 4.254 | .000 |
| | Non-obese | 99.48 | 8.416 | 1.190 | | |
| Baseline DBP | Obese | 70.00 | 4.571 | .646 | 3.175 | .002 |
| | Non-obese | 67.28 | 3.975 | .562 | | |
| Valsalva Ratio | Obese | 1.5618 | .15911 | .02250 | -10.172 | .000 |
| | Non-obese | 1.8358 | .10471 | .01481 | | |
| DBP rise in IHGT | Obese | 15.52 | 2.002 | .283 | -5.939 | .000 |
| | Non-obese | 17.60 | 1.457 | .206 | | |
| DBP rise in CPT | Obese | 11.16 | 1.570 | .222 | -10.840 | .000 |
| | Non-obese | 14.56 | 1.567 | .222 | | |

Table No.14: comparison of parameters in obese and non-obese subjects.

**Results conclusion comparing obese and non-obese subjects**

The analysis of parameters comparing obese and non-obese individuals reveals significant differences across multiple parameters, highlighting the substantial effects of obesity on both pulmonary and autonomic functions.

- Age: The obese group had a slightly higher average age (mean: 20.24 years) compared to the non-obese group (mean: 19.64 years), with a statistically significant difference ($p = 0.009$).
- Height: The obese group had significantly greater height (mean: 162.56 cm) compared to the non-obese group (mean: 154.84 cm), with a highly significant difference ($p = 0.0005$), indicating that taller individuals may be more prone to obesity, or obesity is less likely to affect height.
- Weight: The obese group had significantly higher weight (mean: 82.68 kg) compared to the non-obese group (mean: 73.66 kg), with a significant difference ($p = 0.02$). This is consistent with the clinical definition of obesity, where weight is a key factor.
- BMI: As expected, the obese group had a significantly higher BMI (mean: 30.81) compared to the non-obese group (mean: 22.75), with a highly significant difference ($p = 0.000$). This is a defining characteristic of obesity.
- Pulmonary Function: In terms of pulmonary function, the obese group had significantly lower FVC (mean: 3.01 L) compared to the non-obese group (mean: 3.27 L), with a p-value of 0.002, indicating that obesity may be associated with reduced lung capacity. The FEV1 value for the obese group was 2.64 L (mean), while for the non-obese group it was 2.79 L (mean), showing a lower FEV1 in obese individuals, the difference is not statistically significant with P value 0.076. The $FEV_1$/ FVC ratio of obese group is 87.90% (mean), and for the non-obese group, it is 85.41% (mean). The difference

between these two groups is not statistically significant (p =0.231), suggesting that while the obese group has reduced lung capacity, their airflow may not be as significantly impaired as one might expect based on the FVC results.

- Baseline cardiovascular parameters: The obese group showed higher baseline heart rate (mean: 82.40 bpm) compared to the non-obese group (mean: 75.12 bpm), with a highly significant difference (p = 0.001). Similarly, baseline systolic blood pressure (SBP) was higher in the obese group (mean: 106.80 mmHg) compared to the non-obese group (mean: 99.48 mmHg), with a significant difference (p = 0.000). A significant difference was also observed in baseline diastolic blood pressure (DBP) (p = 0.002), with the obese group having higher values (mean: 70.00 mmHg) than the non-obese group (mean: 67.28 mmHg).

- Valsalva Ratio: The obese group had a significantly lower Valsalva ratio (mean: 1.56) compared to the non-obese group (mean: 1.84), with a highly significant difference (p = 0.000), suggesting diminished parasympathetic reactivity in obese individuals.

- DBP Rise in IHGT and CPT: Both DBP rise in IHGT and DBP rise in CPT were significantly lower in the obese group (mean: 15.52 and 11.16, respectively) compared to the non-obese group (mean: 17.60 and 14.56, respectively), with p-values of 0.000 for both. This indicates a diminished sympathetic reactivity response to stress in the obese group.

| PARAMETER | MALE OBESE | FEMALE OBESE | P VALUE |
|---|---|---|---|
| **AGE** | 20.32 ±1.28SD | 20.16±1.15 | 0.6 |
| **HEIGHT** | 162.56±8.78 | 154.84±5.08 | 0.0005 |
| **WEIGHT** | 82.68±19.00 | 73.66±5.21 | 0.02 |
| **BMI** | 31.15±3.42 | 30.47±0.43 | 0.3 |
| **BASELINE HR** | 84.72±6.71 | 80.08±8.66 | 0.03 |
| **BASELIE SBP** | 10±8.40 | 107.6±8.90 | 0.51 |
| **BASELINE DBP** | 71.04±5.06 | 68.96±3.62 | 0.1 |
| **FVC** | 3.08±0.52 | 2.93±0.32 | 0.22 |
| **FEV1** | 2.58±0.56 | 2.68±0.39 | 0.46 |
| **FEV1/FVC** | 84.56±15.23 | 91.23±7.28 | 0.05 |
| **VALSALVA RATIO** | 1.52±0.17 | 1.59±0.13 | 0.10 |
| **DBP RISE IN IHGT** | 16.72±1.68 | 14.32±1.46 | 0.0001 |
| **DBP RISE IN CPT** | 11.68±1.56 | 10.64±1.35 | 0.015 |

*< 0.05 Significant difference

**>0.05 not significant.

Table No.15: Comparison of Parameters in male obese and female obese subjects

**Result conclusion comparing male obese and female obese:**

The data presented in the table above highlights several differences between male and female obese individuals across various parameters. Age does not show a significant difference between males (20.32 ± 1.28 years) and females (20.16 ± 1.15 years), with a p-value of 0.6, suggesting that age is similar across both groups. However, height is significantly greater in males (162.56 ± 8.78 cm) compared to females (154.84 ± 5.08 cm), with a p value of 0.0005,

showing considerable difference between genders. Similarly, weight also differs significantly, with males averaging 82.68 ± 19.00 kg and females 73.66 ± 5.21 kg ($p = 0.02$), which aligns with the differences in height.

Despite these differences in height and weight, the body mass index (BMI) does not show a major difference between genders, with males having an average BMI of 31.15 ± 3.42 and females 30.47 ± 0.43 ($p = 0.3$), suggesting similar levels of obesity in both groups. In terms of cardiovascular parameters, baseline heart rate (HR) is significantly higher in males (84.72 ± 6.71 bpm) than females (80.08 ± 8.66 bpm), with a p value of 0.03, showing a gender-based difference in baseline heart rate. However, baseline systolic blood pressure and diastolic blood pressure do not show significant differences, with p-values of 0.51 and 0.1, respectively.

Regarding pulmonary function, both forced vital capacity and forced expiratory volume in 1 sec did not show significant differences between males and females, with p-values of 0.22 and 0.46, respectively. However, the FEV1/FVC ratio, which can indicate restrictive or obstructive lung disease, is approaching significance ($p = 0.05$), suggesting a potential but not definitive difference between the genders.

Finally, in terms of autonomic function, DBP rise in the Isometric Handgrip Test and cold pressor test are significantly higher in male obese individuals (p-values of 0.0001 and 0.015, respectively), indicating that males may experience a stronger autonomic response to these stress tests compared to females.

In conclusion, while age appears similar across both groups, significant differences between male and female obese individuals are observed in height, weight, baseline heart rate, and autonomic responses. On the other hand, parameters such as BMI, pulmonary function, and baseline blood pressure do not show significant gender-based differences. This suggests that

while obesity has distinct effects on males and females in certain areas, its impact on pulmonary function and overall blood pressure appears to be comparable across genders.

**Results comparison between female obese and non-obese:**

| PARAMETER | FEMALE OBESE | FEMALE NON-OBESE | P VALUE |
|---|---|---|---|
| **AGE** | 20.16±1.15SD | 19.52±0.94 | 0.03 |
| **HEIGHT** | 154.84±5.08 | 160.6±5.08 | 0.0002 |
| **WEIGHT** | 73.36±5.21 | 59.05±8.31 | 0.0001 |
| **BMI** | 30.47±0.43 | 22.58±2.22 | 0.0001 |
| **BASELINE HR** | 80.08±8.66 | 73.12±6.45 | 0.002 |
| **BASELIE SBP** | 107.60±8.90 | 100.24±8.69 | 0.004 |
| **BASELINE DBP** | 68.96±3.62 | 67.12±4.23 | 0.105 |
| **FVC** | 2.93±0.32 | 3.12±0.24 | 0.02 |
| **FEV1** | 2.68±0.39 | 2.69±0.28 | 0.9175 |
| **FEV1/FVC** | 91.23±7.28 | 86.383±7.40 | 0.023 |
| **VALSALVA RATIO** | 1.59±0.13 | 1.83±0.11 | 0.00001 |
| **DBP RISE IN IHGT** | 14.32±1.46 | 17.52±1.46 | 0.0001 |
| **DBP RISE IN CPT** | 10.64±1.35 | 14.48±1.62 | 0.0001 |

Table No.16: Comparison of Parameters between female obese and non-obese subjects.

**Results conclusion of comparison between female obese and non-obese subjects.**

The above table shows comparison results between female obese and non-obese subjects across various physiological parameters. The mean age for obese females was 20.16 ± 1.15 years,

while for non-obese females it was 19.52 ± 0.94 years (p = 0.03), with obese females being slightly older. In terms of physical characteristics, obese females had a significantly higher weight (73.36 ± 5.21 kg vs. 59.05 ± 8.31 kg, p = 0.0001) and BMI (30.47 ± 0.43 vs. 22.58 ± 2.22, p = 0.0001). Additionally, they were shorter in height (154.84 ± 5.08 cm vs. 160.6 ± 5.08 cm, p = 0.0002). Regarding baseline parameters, obese females exhibited a higher baseline heart rate (80.08 ± 8.66 bpm vs. 73.12 ± 6.45 bpm, p = 0.002) and systolic blood pressure (107.60 ± 8.90 mmHg vs. 100.24 ± 8.69 mmHg, p = 0.004). However, there was no significant difference in diastolic blood pressure (68.96 ± 3.62 mmHg vs. 67.12 ± 4.23 mmHg, p = 0.105). Pulmonary function tests revealed that obese females had a significantly lower forced vital capacity (FVC) (2.93 ± 0.32 L vs. 3.12 ± 0.24 L, p = 0.02) and a higher FEV1/FVC ratio (91.23 ± 7.28% vs. 86.38 ± 7.40%, p=0.023). There is no significant difference no significant difference in FEV1 (2.68 ± 0.39L vs 2.69 ± 0.28 L,p =0.9175).Furthermore, autonomic functions were affected, with obese females showing a significantly lower Valsalva ratio (1.59 ± 0.13 vs. 1.83 ± 0.11, p = 0.00001) and a low rise in diastolic blood pressure during the isometric handgrip test (14.32 ± 1.46 mmHg vs. 17.52 ± 1.46 mmHg, p = 0.0001) and cold pressor test (10.64 ± 1.35 mmHg vs. 14.48 ± 1.62 mmHg, p = 0.0001).

These results indicate that obesity in females is associated with significant alterations in both pulmonary and autonomic functions. Pulmonary function, as measured by FVC, appears to be compromised in obese females, while FEV1 remains similar between groups. Additionally, obese females show signs of altered autonomic regulation, evidenced by a lower Valsalva ratio and a diminished increase in diastolic blood pressure in response to isometric handgrip and cold pressor tests, which suggests diminished autonomic function.

# Correlation Matrix

| Variable | Age | BMI | FVC | FEV 1 | FEV 1/FVC | Baseline HR | Baseline SBP | Baseline DBP | Valsalva Ratio | RISE DBP IHGT | RISE DBP CPT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Age** | 1 | .267** | .070 | .104 | .063 | .014 | .133 | .167 | -.170 | -.259** | -.131 |
| **BMI** | .267** | 1 | -.327** | -.165 | .158 | -.084 | .324** | .286** | -.672** | -.470** | -.644** |
| **FVC** | .070 | -.327** | 1 | .662** | -.184 | .000 | -.148 | -.150 | .132 | .209* | .213* |
| **FEV 1** | .104 | -.165 | .662** | 1 | .606** | -.084 | -.013 | .119 | .100 | .039 | .155 |
| **FEV 1/FVC** | .063 | .158 | -.184 | .606** | 1 | -.114 | .114 | .297** | -.031 | -.178 | -.049 |
| **Baseline HR** | .014 | -.084 | .000 | -.084 | -.114 | 1 | -.001 | .060 | -.002 | .151 | .087 |
| **Baseline SBP** | .133 | .324** | -.148 | -.013 | .114 | -.001 | 1 | .665** | -.247* | -.228* | -.258** |
| **Baseline DBP** | .167 | .286** | -.150 | .119 | .297** | .060 | .665** | 1 | -.179 | -.053 | -.112 |
| **Valsalva Ratio** | -.170 | -.672** | .132 | .100 | -.031 | -.002 | -.247* | -.179 | 1 | .389** | .519** |
| **RISE DBP IHGT** | -.259** | -.470** | .209* | .039 | -.178 | .151 | -.228* | -.053 | .389** | 1 | .515** |
| **RISE DBP CPT** | -.131 | -.644** | .213* | .155 | -.049 | .087 | -.258** | -.112 | .519** | .515** | 1 |

Table No.17: Corelation matrix between different parameters.

Note:

- P<0.01(highly significant) is marked as ****
- P < 0.05 (significant) is marked as *
- Non-significant correlations are unmarked.

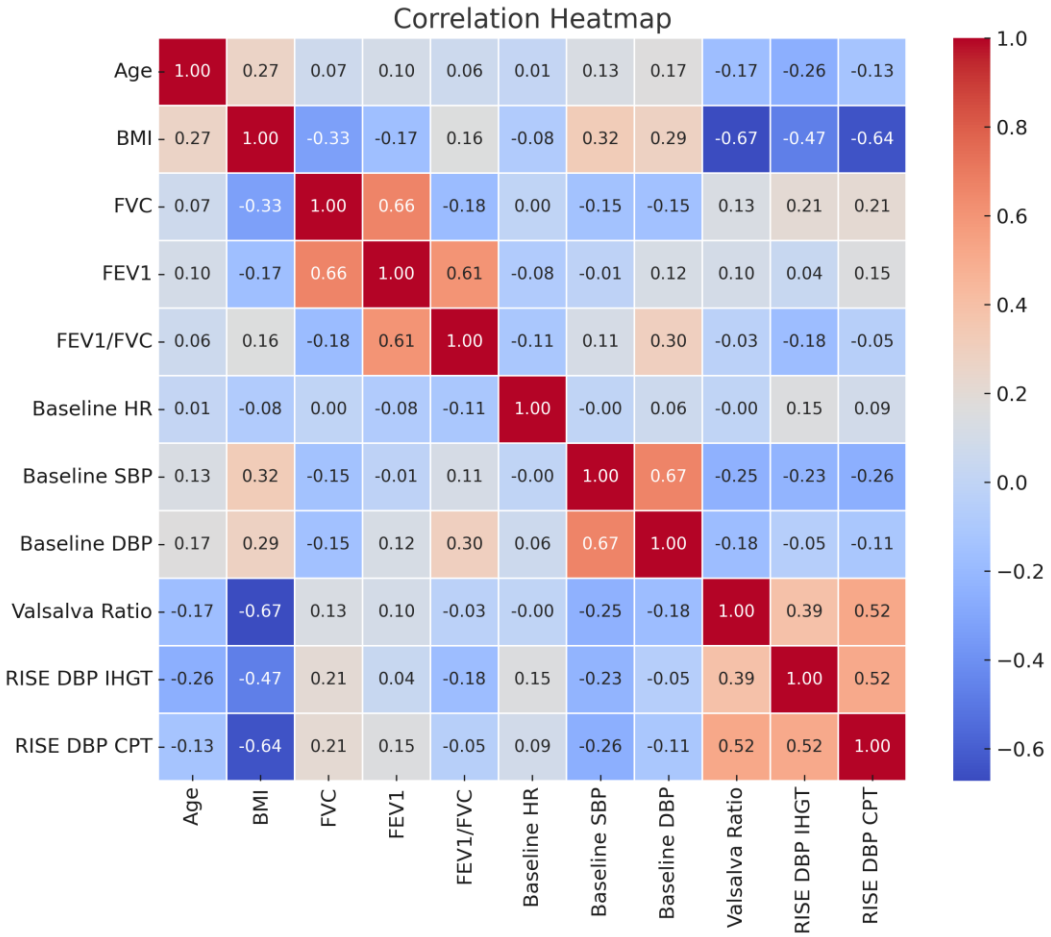


Figure No.25: Correlation Heat map

**Interpretation of the Correlation Matrix**

1. Age and BMI: There is a significant positive correlation ($r = 0.267$, $p<0.01$), indicating that as age increases, BMI tends to increase.

2. BMI and FVC: a significant negative correlation ($r= -0.327$, $p<0.01$) suggests that higher BMI is associated with lower FVC.

3. FVC and FEV1: a strong positive correlation ($r =0.662$, $p<0.01$) shows that higher FVC values are associated with higher FEV1 values.

4. FEV1 and FEV1/FVC: A strong positive correlation ($r = 0.606$, $p < 0.01$) suggests that as FEV1 increases, the ratio of FEV1 to FVC also increases.

5. BMI and Baseline SBP: A significant positive correlation ($r = 0.324$, $p < 0.01$) indicates that individuals with higher BMI tend to have higher baseline systolic blood pressure.

6. BMI and Valsalva Ratio: A strong negative correlation ($r = -0.672$, $p < 0.01$) suggests that as BMI increases, Valsalva Ratio decreases, which may indicate impaired autonomic function in individuals with higher BMI.

7. Baseline SBP and Baseline DBP: A strong positive correlation ($r = 0.665$, $p < 0.01$) suggests that systolic and diastolic blood pressure tend to increase together.

8. Valsalva Ratio and rise in DBP IHGT/CPT: Both rise in DBP in IHGT ($r = 0.389$, $p < 0.01$) and rise in DBP in CPT ($r = 0.519$, $p < 0.01$) show significant positive correlations with the Valsalva Ratio, indicating a potential link between autonomic function and blood pressure response.

**Conclusion of correlation analysis**

This correlation analysis highlights significant associations between BMI, lung function, blood pressure, and autonomic responses. The strong negative relationship between BMI and Valsalva Ratio suggests that higher BMI may impair autonomic function. Additionally, FVC and FEV1 are highly correlated, reflecting normal physiological relationships. These insights can be useful for clinical and research purposes.

## DISCUSSION

This study aimed to compare the pulmonary and autonomic functions between obese and non-obese individuals within the 18–25-year age group.

Age and body mass index (BMI)

In this study, the mean age of obese individuals (20.24 ± 1.238) was significantly higher than that of non-obese individuals (19.64 ± 1.005), highlighting a notable difference between the two groups. These findings align with those of Amudha Poobhalan et al. (2016)[26] whose research indicated that the average age at which individuals transition to being overweight or obese is between 20 and 29 years. Similarly, a study by Nitish Kumar et al. (2024)[18] observed a positive correlation between age and obesity, suggesting that as individuals age, their body mass index (BMI) tends to increase.

**Pulmonary Function and BMI**

In this study the mean forced vital capacity FVC among obese individuals was 3.01 ± 0.45liters, among non-obese it was 3.27 ± 0.36 Liters there is statistically significant reduction in the volume, these results show there is reduction in the volume in obese individuals compared to non-obese. The result of this study closely matches with the earlier studies done by Nitish Kumar et al, (2024)[18] Kanchanmala, et al. (2024)[21] Abdullah et al. (2023)[19] and Devershetty et al. (2015)[26]and few other studies. The study done by Md. Mahboob Alam et al. (2016)[25] results were completely opposite to this study where FVC was increased with weight gain.

The forced expiratory volume per 1 sec ($FEV_1$) reduced in obese individuals in compared to their counter group, the reduction is not statistically significant ($p>0.05$). The FEV1 mean was 2.63 ± 0.49 Litres in obese individuals 2.79 ± 0.38 litres. The results of this study were n concurrence with other studies done by Shashi Mahajan et al, (2020)[22] which was done on medical students. Another study done by Shinde, et al. (2018)[24] to assess the impairment of

forced expiratory lung functions due to obesity in adults showed similar results. Contrary to our study, a study done by Bhattacharjee et al. (2018) showed increased $FEV_1$ with obesity.

In this present study the $FEV_1$ /FVC ratio is slightly higher in obese individuals 87.90 ± 12.52 than in non-obese individuals 85.41 ± 7.42 with p-value 0.231 indicating there is no statistically significant difference. The results of this study match with the results of study done by Shashi Mahajan et al. (2020)[22] where $FEV_1$ /FVC ratio was increased in one of their study groups.

The decreased FVC and FEV1 values with slightly increase in $FEV_1$/FVC ratio in obese individuals suggests a restrictive lung pattern.[58] The results of this study conclude that BMI has negative impact on the pulmonary functions.

**Autonomic Function and BMI**

In addition to the pulmonary function tests, this study also assessed the autonomic function in obese and non-obese individuals using various tests designed to assess parasympathetic and sympathetic activity.

Baseline heart rate, systolic blood pressure and diastolic blood pressure were high in obese individuals relative to normal weight individual's, this was stated by many studies in literature which evaluated the impact of obesity on cardiovascular parameters. In this present study the mean heart rate, systolic blood pressure, diastolic blood pressure in obese individuals are 82.40 ± 8.17, 106.80 ± 8.79, 70.00 ± 4.57 respectively which were statistically significant when compared to non-obese individuals. The present study results are in agreement with the results of study done by Afreen Begum Itagi et al. (2021)[35], Renata Claudino Rossi, et al. (2015)[46]

In this study the mean Valsalva ratio is lower in obese individuals (1.56 ± 0.16) than in non-obese individuals (1.83 ± 0.10) which is statistically significant with p-value (.000), though the ratio value is reduced it is normal limits of Valsalva ratio. The study results are in line with the study results which was done by M. Janet Sugantha et al. (2019)[37]and similar study done by

Rinku Garg et al. (2013)[48] How ever, a study done by Cloak, et al. (2000)[51] the results of their study contrasted with this study.

The diastolic blood pressure rise in response to the isometric handgrip test was low in obese individuals compared to non-obese, the mean diastolic blood pressure increase is lower in obese individuals (15.52 ± 2.00) than in non-obese individuals (17.60 ± 1.46) which highly significant statistically (P<0.05). The obese subjects who underwent cold pressor test in this study show a lower rise in DBP (11.16 ± 1.57) compared to non-obese individuals (14.56 ± 1.57) with p-value (.000) indicating a highly significant difference, suggesting that obese individuals have a reduced sympathetic response to cold stress. The results of both isometric hand grip test and cold pressor test were in line with the study done Siva kumar AV, et al,(2016)[50] Kirti Goyal et al,(2018)[40] Debasish, et al,(2019)[42] Harish Mohan, et al. (2019)[39]Another study done by Pavithra elayaperumal, et al. (2018)[41] their findings did not support present study results, as they found no effect of obesity on autonomic functions.

**Relationship Between BMI, Pulmonary and Autonomic Functions**

The key findings of this study is the negative correlation between body mass index (BMI) and both pulmonary and autonomic functions. As BMI increases, both pulmonary function (FVC, FEV1) and autonomic regulation (parasympathetic and sympathetic responses) decline. This aligns with previous research, which has demonstrated that higher BMI is related to elevated risk of both pulmonary and autonomic dysfunction. The adverse effects of obesity on the autonomic nervous system and pulmonary function further emphasize the systemic impact of obesity, emphasizing the need for early intervention and management of obesity to reduce its long-term effects on health.

## Clinical Utility of Findings: Implications for Screening and Intervention

This study provides important insights into the negative impact of obesity on both pulmonary and autonomic functions in individuals aged 18–25. The findings are highly relevant in clinical practice, particularly when considering how they could contribute to screening and intervention strategies for obesity-related health issues.

### Pulmonary Function and Obesity

The study demonstrates that obesity is associated with a decrease in pulmonary function, specifically a reduction in forced vital capacity (FVC) and forced expiratory volume in 1 sec ($FEV_1$). The reduced pulmonary function observed in obese individuals, as indicated by lower FVC and FEV1 values, points to the need for early screening for respiratory dysfunction in this population. Obesity has been shown to impair lung function, often leading to a restrictive lung pattern, which may predispose individuals to further respiratory complications, such as obstructive sleep apnoea, pulmonary hypertension, and other pulmonary diseases. The negative correlation between BMI and pulmonary function in this study supports the need for routine pulmonary assessments, particularly for individuals who are overweight or obese. Clinicians could consider incorporating pulmonary function tests (PFTs) into regular health checkups for obese individuals, especially in those with comorbidities.

### Autonomic Function and Obesity

The findings of this study also indicate that obesity negatively impacts autonomic function, as evidenced by elevated baseline heart rate, blood pressure, and a reduced response to stress tests such as the Valsalva ratio, isometric hand grip test, and cold pressor test. These changes point to dysregulation of both parasympathetic and sympathetic responses, increasing the risk of cardiovascular disorders. The reduced sympathetic response observed in obese individuals could contribute to a higher risk of developing cardiovascular complications later in life.

Clinically, these findings suggest that obesity should not only be managed through weight control but also through cardiovascular monitoring. Routine monitoring of heart rate variability, blood pressure, and autonomic function in obese individuals can help detect early signs of autonomic dysfunction. Early interventions such as physical activity promotion, stress management techniques, and lifestyle changes can potentially improve autonomic regulation and reduce the long-term cardiovascular risks associated with obesity.

**Integration with Indian National Health Data and Burden Estimation**

Obesity is a growing health concern in India, with an increasing prevalence among young adults, particularly in urban areas. According to national health surveys, the prevalence of obesity among Indian adults has been rising steadily, and the burden of obesity-related diseases, including diabetes, hypertension, and cardiovascular disease, is expected to increase significantly in the coming decades. Studies like this one, which demonstrate the adverse effects of obesity on pulmonary and autonomic functions, highlight the need for targeted interventions to address the obesity epidemic early, especially in young adults.

In India, where the burden of non-communicable diseases (NCDs) is on the rise, obesity contributes significantly to this public health challenge. Incorporating obesity management and prevention strategies into national health policies can help curb the prevalence of obesity-related diseases. Screening for pulmonary and autonomic dysfunction in obese individuals could be an essential part of these interventions. Early intervention through lifestyle changes, including diet modification, physical activity, and weight management, could be critical in reducing the long-term healthcare burden of obesity and its associated complications.

## LIMITATIONS OF THIS STUDY

This study has several limitations that must be considered. Firstly, it was conducted with a limited sample population, which primarily consisted of individuals who were already aware of obesity and its associated health risks. While the small sample size is acknowledged, there was no quantitative post-hoc power analysis to assess whether the sample was sufficient to draw definitive conclusions.

Moreover, the study did not account for important factors such as the type of obesity, peripheral or abdominal, duration of obesity, or variations in physical activity levels. This omission limits the comprehensiveness of the findings. The small sample size of obese subjects also restricts the generalizability of the results to the wider population.

Additionally, potential selection bias was not addressed, as participants were primarily medical students who may possess greater health awareness than the general population. The study also did not consider the impact of pubertal or endocrine changes in the 18–25 age group, which could have influenced the results. Finally, the lack of a follow-up or longitudinal component limits the ability to make causal or temporal inferences based on the data. These factors collectively suggest that caution should be taken when interpreting the study's findings.

# SUMMARY AND CONCLUSION.

## SUMMARY

A study was carried out to compare pulmonary function and autonomic function in obese and non-obese individuals of age group 18 to 25 years. The study was held at department of physiology of Santosh medical college, in which 100 individuals were included of both genders. At first, according to inclusion and exclusion criteria anthropometric parameters of subjects are measured, like height, weight and BMI. After calculation of BMI these subjects been categorised to obese and non-obese individuals.

The next step after grouping of subjects was to assess the functions of pulmonary system, which is done by using spirometry with the help of spirometer. The parameters which were measured were FVC, $FEV_{1,}$ $FEV_1/FVC$. To know the integrity of the autonomic functions among obese and non-obese autonomic a series of non-invasive function tests are performed. The test which is used to assess the parasympathetic activity is Valsalva manoeuvre, for sympathetic activity isometric hand grip test and cold pressor tests. Data been collected and statistical analysis was done by calculating mean and standard deviation and using student's t test.

The anthropometric findings of this study showed significant difference, the results of pulmonary function parameters forced vital capacity (FVC), forced expiratory volume per 1 sec ($FEV_1$) are reduced and $FEV_1/FVC$ ratio is increased in obese in compared to non-obese. The results of autonomic functions like parasympathetic activity and sympathetic activity are reduced in obese individuals compared to non- obese individuals.

This study also revealed a negative correlation between Body Mass Index (BMI) and both pulmonary and autonomic functions, meaning that as BMI increases, the negative impact on these functions intensifies.

## CONCLUSION

In conclusion, this study demonstrates that obesity has significant effects on both pulmonary and autonomic function in young adults of age group 18-25 years. Overall findings of this study highlight the importance of addressing obesity early in life to prevent long-term health consequences, particularly in terms of respiratory and cardiovascular health.

The findings from this study emphasize the critical need for early intervention to address obesity and its impact on respiratory and cardiovascular health. Obesity during young adulthood, particularly in the 18-25-year age group, can have lasting consequences on both lung function and the autonomic nervous system. These early alterations in physiological functions may set the stage for chronic health issues in the future. Therefore, adopting strategies for the prevention and management of obesity at this stage is essential. Promoting regular physical activity, encouraging a healthy lifestyle, and fostering the adoption of a balanced diet can significantly mitigate the negative effects of obesity on lung and autonomic function. By prioritizing early intervention and encouraging healthy lifestyle choices, we can significantly lessen the risk of long-term health complications and enhance overall well-being for young adults.

Ultimately, this study highlights that addressing obesity not only helps prevent respiratory and cardiovascular disorders but also contributes to the broader goal of improving the quality of life for individuals.

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# INFORMED CONSENT

Patient identification number for this study: _____

Title of study **Comparison of Pulmonary Functions And Autonomic Functions In Obese and Non-Obese Individuals Aged Between 18 to 25 Years** Name of Principal Investigator: **Dr. Katkam Sai Arjun** The contents of the information sheet dated _____ that was provided have been read carefully by me /explained in detail to me, in a language that I comprehend, and I have fully understood the contents. I confirm that I have had the opportunity to ask questions. The nature and purpose of the study and its potential risks/ benefits and expected duration of the study, and other relevant details of the study have been explained to me in detail. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal right being affected. I understand that the information collected about me in this research and sections of any of my medical notes may be looked at by responsible individuals. I agree to take part in the above study.

……. Date:

(Signature/Left Thumb impression) Place:

Name of the Participant: _____

Son/Daughter/Spouse of: _____

Complete postal address: _____

This is to certify that the above consent has been obtained in my presence.

…….. Date:

Signatures of the Principal Investigator Place:

# SUBJECT INFORMATION FORM

Name:

Age:

Gender:

Personal History:

Family History:

Drug History:

Physical activity:

Menstrual cycle:

Sleep patterns:

Height:

Weight:

Body Mass Index: _____

Blood Pressure: Systolic _____ Diastolic_____

Heart Rate: _____

**PULMONARY FUNCTION TESTS**:

| Parameter | I Reading | II Reading | III Reading |
|---|---|---|---|
| FVC | | | |
| $FEV_1$ | | | |
| $FEV_1/FVC$ | | | |

**AUTONOMIC FUNCTIONS TESTS**:

To assess Parasympathetic activity Valsalva Maneuvre

| Lowest Heart Rate during Phase II | Longest Heart rate during phase IV | Valsalva Ratio |
|---|---|---|
| | | |

Valsalva Maneuvre ratio:

Ratio >/= 1.2 is normal

**TO ASSESS SYMPATHETIC SYSTEM**

**Cold Pressor Test:**

| DBP During procedure | Baseline DBP | Difference in DBP |
|---|---|---|
| | | |

Diastolic blood pressure difference >/= 10mm of hg is considered as normal.

**Isometric Hand Grip Test:**

| DBP During procedure | Baseline DBP | Rise of DBP |
|---|---|---|
| | | |

Diastolic blood Pressure rise >/= 16mm of hg is considered as normal

# MASTER CHART

| S. No. | Age | M/F | Height | Weight | BMI | OBESE/NON OBESE | FVC | FEV 1 | FEV 1/FVC | Baseline HR | Baseline SBP | Baseline DBP | Valsalva Ratio | RESULTS OF RISE OF DBP IN ISOMETRIC HANDGRIP TEST (IHGT) | RESULTS OF RISE OF DBP IN COLD PRESSOR TEST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 19 | F | 161 | 60 | 23.1 | NON OBESE | 3.28 | 2.88 | 87.8 | 72 | 90 | 60 | 1.87 | 16 | 14 |
| 2 | 20 | M | 173 | 77 | 25.7 | NON OBESE | 3.21 | 2.6 | 80.99 | 80 | 90 | 62 | 1.9 | 18 | 16 |
| 3 | 18 | M | 180 | 68 | 21 | NON OBESE | 3.17 | 2.76 | 89.03 | 84 | 90 | 60 | 1.7 | 20 | 16 |
| 4 | 19 | M | 167 | 72 | 25.8 | NON OBESE | 3.38 | 2.81 | 83.14 | 72 | 88 | 60 | 2 | 18 | 16 |
| 5 | 21 | M | 186 | 80 | 24.7 | NON OBESE | 3.16 | 2.64 | 83.54 | 68 | 90 | 70 | 1.9 | 16 | 16 |
| 6 | 21 | M | 186 | 80 | 23.1 | NON OBESE | 3.21 | 2.88 | 89.72 | 72 | 90 | 64 | 1.84 | 18 | 14 |
| 7 | 21 | M | 173 | 73 | 24.4 | NON OBESE | 3.56 | 2.92 | 82.02 | 88 | 90 | 70 | 2 | 20 | 16 |
| 8 | 20 | F | 160 | 62 | 24.2 | NON OBESE | 3.27 | 2.68 | 81.96 | 84 | 88 | 56 | 1.75 | 18 | 16 |
| 9 | 21 | F | 155 | 63 | 26.2 | NON OBESE | 3.36 | 2.76 | 82.14 | 72 | 92 | 68 | 1.72 | 16 | 14 |
| 10 | 19 | F | 163 | 55 | 20.7 | NON OBESE | 3.31 | 2.64 | 79.76 | 64 | 92 | 64 | 1.64 | 18 | 14 |
| 11 | 20 | F | 166 | 55 | 20 | NON OBESE | 3.29 | 2.61 | 79.33 | 68 | 92 | 68 | 1.7 | 16 | 12 |
| 12 | 18 | F | 168 | 58 | 20.5 | NON OBESE | 3.34 | 2.68 | 80.24 | 80 | 100 | 60 | 1.84 | 18 | 10 |
| 13 | 18 | M | 169 | 59 | 20.7 | NON OBESE | 3.38 | 2.72 | 80.47 | 96 | 102 | 70 | 1.8 | 20 | 12 |
| 14 | 19 | M | 166 | 54 | 19.6 | NON OBESE | 2.65 | 1.97 | 74.34 | 80 | 110 | 70 | 2 | 18 | 14 |
| 15 | 19 | F | 167 | 56 | 20.1 | NON OBESE | 3.36 | 3.36 | 100 | 72 | 108 | 70 | 1.9 | 18 | 16 |
| 16 | 20 | F | 167 | 55 | 19.7 | NON OBESE | 3.34 | 2.68 | 80.24 | 68 | 114 | 72 | 1.84 | 16 | 16 |
| 17 | 20 | F | 151 | 53 | 23.2 | NON OBESE | 3.16 | 2.72 | 86.08 | 72 | 120 | 70 | 1.72 | 18 | 16 |
| 18 | 21 | F | 158 | 60 | 24 | NON OBESE | 3.17 | 2.58 | 81.39 | 72 | 100 | 70 | 1.64 | 16 | 16 |
| 19 | 19 | F | 161 | 60 | 23.1 | NON OBESE | 2.98 | 2.57 | 86.24 | 80 | 108 | 70 | 1.87 | 18 | 14 |
| 20 | 18 | F | 163 | 56 | 21.1 | NON OBESE | 2.65 | 2.41 | 90.94 | 72 | 90 | 64 | 1.9 | 20 | 16 |
| 21 | 20 | F | 161 | 56 | 21.6 | NON OBESE | 2.56 | 2.47 | 96.48 | 80 | 90 | 64 | 1.7 | 18 | 14 |
| 22 | 19 | F | 167 | 68 | 24.4 | NON OBESE | 2.76 | 2.39 | 86.6 | 72 | 100 | 70 | 2 | 20 | 16 |
| 23 | 20 | M | 169 | 60 | 21 | NON OBESE | 2.98 | 2.72 | 91.28 | 76 | 100 | 68 | 1.75 | 20 | 16 |
| 24 | 19 | M | 173 | 68 | 22.7 | NON OBESE | 3.28 | 3.17 | 96.65 | 72 | 96 | 70 | 1.72 | 18 | 14 |
| 25 | 20 | M | 185 | 75 | 21.9 | NON OBESE | 3.02 | 2.5 | 82.78 | 80 | 90 | 64 | 1.87 | 16 | 12 |
| 26 | 19 | F | 163 | 57 | 21.5 | NON OBESE | 3.05 | 2.38 | 78.03 | 68 | 90 | 64 | 1.9 | 18 | 14 |
| 27 | 20 | M | 167 | 72 | 25.8 | NON OBESE | 4.24 | 3.22 | 75.94 | 72 | 94 | 68 | 1.8 | 16 | 12 |
| 28 | 20 | M | 165 | 56 | 20.6 | NON OBESE | 3.22 | 2.37 | 73.6 | 702 | 100 | 70 | 1.8 | 20 | 16 |
| 29 | 21 | M | 162 | 61 | 23.2 | NON OBESE | 3.91 | 3.22 | 82.35 | 74 | 110 | 70 | 1.8 | 18 | 14 |
| 30 | 20 | M | 175 | 68 | 22.2 | NON OBESE | 3.07 | 2.89 | 94.14 | 80 | 108 | 70 | 1.9 | 16 | 16 |
| 31 | 20 | F | 151 | 46 | 20.2 | NON OBESE | 3.29 | 3.28 | 99.7 | 84 | 104 | 68 | 2 | 18 | 14 |
| 32 | 19 | F | 158 | 58 | 23.2 | NON OBESE | 3.22 | 3.05 | 94.74 | 88 | 110 | 70 | 1.9 | 16 | 16 |
| 33 | 21 | M | 179 | 75 | 23.2 | NON OBESE | 3.92 | 3.22 | 82.14 | 92 | 120 | 70 | 1.8 | 18 | 12 |
| 34 | 20 | M | 166 | 53 | 19.2 | NON OBESE | 3.56 | 3.28 | 92.13 | 88 | 104 | 70 | 1.7 | 18 | 16 |
| 35 | 21 | M | 169 | 65 | 22.8 | NON OBESE | 4.12 | 3.92 | 95.15 | 80 | 100 | 70 | 1.8 | 16 | 14 |
| 36 | 18 | F | 160 | 52 | 20.3 | NON OBESE | 3.5 | 3.09 | 88.29 | 72 | 90 | 60 | 1.9 | 16 | 16 |
| 37 | 18 | M | 179 | 64 | 20 | NON OBESE | 3.37 | 2.47 | 73.3 | 68 | 96 | 60 | 2 | 18 | 14 |
| 38 | 19 | M | 152 | 56 | 24.2 | NON OBESE | 3.5 | 2.87 | 82 | 72 | 100 | 70 | 1.9 | 20 | 16 |
| 39 | 20 | M | 170 | 68 | 23.5 | NON OBESE | 3.32 | 2.34 | 70.48 | 64 | 96 | 64 | 1.8 | 16 | 14 |
| 40 | 20 | F | 161 | 68 | 26.2 | NON OBESE | 3.01 | 2.77 | 92.03 | 68 | 100 | 70 | 1.72 | 18 | 16 |
| 41 | 21 | F | 172 | 74 | 25 | NON OBESE | 2.96 | 2.64 | 89.19 | 72 | 100 | 70 | 1.8 | 20 | 14 |
| 42 | 20 | F | 150 | 48 | 21.3 | NON OBESE | 3.34 | 2.36 | 70.66 | 64 | 104 | 70 | 1.9 | 18 | 16 |
| 43 | 19 | F | 159 | 52 | 20.6 | NON OBESE | 2.86 | 2.12 | 74.13 | 68 | 108 | 70 | 2 | 18 | 12 |
| 44 | 18 | F | 151 | 49 | 21.5 | NON OBESE | 3.19 | 2.92 | 91.54 | 80 | 100 | 70 | 2 | 16 | 14 |
| 45 | 18 | M | 159 | 61 | 24.1 | NON OBESE | 2.96 | 2.66 | 89.86 | 72 | 96 | 68 | 1.9 | 16 | 16 |
| 46 | 21 | M | 175 | 82 | 26.8 | NON OBESE | 3.93 | 3.63 | 92.37 | 68 | 100 | 70 | 1.8 | 16 | 16 |
| 47 | 21 | F | 166 | 74 | 26.9 | NON OBESE | 2.74 | 2.46 | 89.78 | 64 | 106 | 70 | 1.9 | 18 | 12 |
| 48 | 20 | F | 156 | 81 | 26.1 | NON OBESE | 3.11 | 2.87 | 92.28 | 72 | 110 | 70 | 1.7 | 16 | 14 |
| 49 | 20 | M | 172 | 64 | 21.6 | NON OBESE | 3.83 | 3.33 | 86.05 | 84 | 100 | 68 | 1.8 | 16 | 14 |
| 50 | 19 | M | 169 | 72 | 25.2 | NON OBESE | 3.69 | 3.23 | 87.53 | 76 | 108 | 70 | 1.7 | 16 | 14 |
| 51 | 20 | M | 162 | 80 | 30.5 | OBESE | 3.41 | 3.33 | 97.65 | 72 | 100 | 72 | 1.87 | 20 | 12 |
| 52 | 22 | M | 162 | 60 | 31 | OBESE | 3.36 | 2.98 | 88.69 | 88 | 104 | 70 | 1.5 | 16 | 10 |
| 53 | 23 | M | 154 | 72 | 30.4 | OBESE | 2.96 | 2.87 | 96.96 | 84 | 104 | 70 | 1.6 | 16 | 12 |
| 54 | 21 | M | 153 | 71 | 30.3 | OBESE | 2.86 | 2.12 | 74.13 | 84 | 100 | 72 | 1.8 | 18 | 12 |
| 55 | 19 | M | 162 | 79 | 30.1 | OBESE | 3.02 | 3.01 | 99.61 | 90 | 100 | 80 | 1.2 | 16 | 12 |
| 56 | 21 | M | 162 | 85 | 32.38 | OBESE | 2.73 | 2.9 | 106.23 | 84 | 100 | 70 | 1.5 | 14 | 10 |
| 57 | 18 | M | 158 | 75 | 30.4 | OBESE | 2.96 | 2.1 | 70.95 | 80 | 100 | 68 | 1.6 | 16 | 12 |
| 58 | 21 | M | 162 | 80 | 30.48 | OBESE | 2.98 | 2.8 | 93.96 | 80 | 100 | 64 | 1.58 | 16 | 12 |
| 59 | 21 | M | 170 | 88 | 30.4 | OBESE | 3.66 | 1.82 | 49.73 | 84 | 100 | 60 | 1.38 | 16 | 12 |
| 60 | 20 | M | 160 | 77 | 30.07 | OBESE | 3.71 | 3.42 | 92.18 | 88 | 110 | 70 | 1.4 | 18 | 14 |
| 61 | 21 | M | 176 | 94 | 30.03 | OBESE | 2.88 | 2.73 | 94.8 | 92 | 110 | 70 | 1.5 | 16 | 12 |
| 62 | 19 | M | 150 | 68 | 30.02 | OBESE | 2.27 | 1.76 | 77.53 | 96 | 110 | 72 | 1.4 | 14 | 12 |
| 63 | 20 | M | 160 | 78 | 30.05 | OBESE | 4.16 | 1.99 | 47.84 | 88 | 96 | 62 | 1.58 | 16 | 10 |
| 64 | 21 | M | 150 | 71 | 31.6 | OBESE | 4.25 | 3.42 | 80.47 | 76 | 104 | 70 | 1.2 | 18 | 12 |
| 65 | 20 | M | 168 | 86 | 30.5 | OBESE | 2.76 | 1.95 | 70.65 | 76 | 110 | 70 | 1.6 | 16 | 12 |
| 66 | 19 | M | 162 | 82 | 31.2 | OBESE | 2.56 | 2.3 | 89.84 | 76 | 120 | 80 | 1.6 | 18 | 14 |
| 67 | 21 | M | 166 | 84 | 30.04 | OBESE | 2.92 | 2.8 | 95.9 | 88 | 120 | 80 | 1.84 | 18 | 16 |
| 68 | 21 | M | 167 | 84 | 30.1 | OBESE | 2.85 | 1.83 | 64.21 | 92 | 116 | 76 | 1.4 | 16 | 14 |
| 69 | 21 | M | 159 | 77 | 30.5 | OBESE | 3.6 | 3.57 | 99.17 | 80 | 110 | 70 | 1.36 | 16 | 12 |
| 70 | 20 | M | 169 | 86 | 30.1 | OBESE | 3.19 | 3.15 | 98.75 | 100 | 120 | 80 | 1.6 | 14 | 10 |
| 71 | 23 | M | 160 | 78 | 30.5 | OBESE | 2.53 | 1.97 | 77.87 | 80 | 116 | 72 | 1.8 | 16 | 10 |
| 72 | 20 | M | 158 | 76 | 30.4 | OBESE | 2.49 | 2.3 | 92.37 | 80 | 100 | 70 | 1.6 | 20 | 10 |
| 73 | 19 | M | 152 | 56 | 24.2 | OBESE | 3.9 | 3 | 76.92 | 80 | 90 | 68 | 1.5 | 20 | 10 |
| 74 | 18 | M | 192 | 150 | 40.7 | OBESE | 2.51 | 1.97 | 78.49 | 88 | 116 | 72 | 1.4 | 16 | 10 |
| 75 | 19 | M | 170 | 130 | 42.9 | OBESE | 2.6 | 2.58 | 99.23 | 92 | 94 | 68 | 1.4 | 18 | 10 |
| 76 | 21 | F | 156 | 74 | 30.4 | OBESE | 3.44 | 3.32 | 96.51 | 80 | 100 | 70 | 1.6 | 16 | 12 |
| 77 | 20 | F | 159 | 76 | 30.1 | OBESE | 3.11 | 2.88 | 92.6 | 76 | 100 | 70 | 1.8 | 14 | 12 |
| 78 | 21 | F | 156 | 74 | 30.4 | OBESE | 3.93 | 3.63 | 92.37 | 76 | 120 | 72 | 1.9 | 14 | 10 |
| 79 | 19 | F | 162 | 80 | 30.5 | OBESE | 2.96 | 2.88 | 97.3 | 88 | 112 | 72 | 1.6 | 14 | 8 |
| 80 | 19 | F | 159 | 77 | 30.5 | OBESE | 2.41 | 2.24 | 92.95 | 80 | 112 | 72 | 1.8 | 14 | 10 |
| 81 | 22 | F | 155 | 76 | 31.6 | OBESE | 2.51 | 2.2 | 87.65 | 92 | 114 | 70 | 1.6 | 14 | 12 |
| 82 | 21 | F | 148 | 66 | 30.1 | OBESE | 3.1 | 2.87 | 92.58 | 72 | 116 | 72 | 1.4 | 16 | 14 |
| 83 | 19 | F | 149 | 68 | 30.6 | OBESE | 3.01 | 2.76 | 91.7 | 72 | 120 | 70 | 1.6 | 16 | 10 |
| 84 | 21 | F | 150 | 68 | 30.2 | OBESE | 2.96 | 2.64 | 89.19 | 68 | 110 | 70 | 1.75 | 14 | 10 |
| 85 | 22 | F | 152 | 70 | 30.3 | OBESE | 3.12 | 2.89 | 92.63 | 72 | 110 | 70 | 1.75 | 14 | 10 |
| 86 | 20 | F | 149 | 70 | 31.5 | OBESE | 2.59 | 2.57 | 99.23 | 72 | 100 | 70 | 1.75 | 14 | 12 |
| 87 | 21 | F | 151 | 72 | 31.6 | OBESE | 2.96 | 2.87 | 96.96 | 72 | 90 | 64 | 1.64 | 12 | 10 |
| 88 | 22 | F | 162 | 79 | 30.1 | OBESE | 2.68 | 2.57 | 95.59 | 88 | 100 | 70 | 1.56 | 12 | 10 |
| 89 | 20 | F | 164 | 82 | 30.5 | OBESE | 3.19 | 2.92 | 91.54 | 92 | 112 | 72 | 1.47 | 14 | 8 |
| 90 | 21 | F | 150 | 68 | 30.2 | OBESE | 3.01 | 2.77 | 92.03 | 96 | 96 | 60 | 1.58 | 14 | 10 |
| 91 | 20 | F | 150 | 69 | 30.7 | OBESE | 2.96 | 2.64 | 89.19 | 64 | 92 | 60 | 1.5 | 12 | 12 |
| 92 | 19 | F | 152 | 69 | 30.3 | OBESE | 2.92 | 2.91 | 99.32 | 92 | 100 | 70 | 1.6 | 16 | 10 |
| 93 | 19 | F | 148 | 66 | 30.1 | OBESE | 2.57 | 2.26 | 87.94 | 92 | 100 | 70 | 1.58 | 16 | 10 |
| 94 | 20 | F | 162 | 80 | 30.5 | OBESE | 2.86 | 2.12 | 74.13 | 72 | 110 | 70 | 1.54 | 16 | 10 |
| 95 | 21 | F | 154 | 72 | 30.4 | OBESE | 2.68 | 2.57 | 95.9 | 78 | 108 | 70 | 1.38 | 12 | 12 |
| 96 | 19 | F | 150 | 68 | 30.2 | OBESE | 2.86 | 2.74 | 95.8 | 80 | 112 | 70 | 1.47 | 12 | 10 |
| 97 | 20 | F | 153 | 71 | 30.3 | OBESE | 2.41 | 1.63 | 67.63 | 88 | 100 | 60 | 1.4 | 14 | 10 |
| 98 | 21 | F | 160 | 78 | 30.5 | OBESE | 2.9 | 2.54 | 87.59 | 84 | 120 | 70 | 1.56 | 16 | 12 |
| 99 | 18 | F | 161 | 85 | 30.1 | OBESE | 3.12 | 3.09 | 99.4 | 80 | 116 | 70 | 1.58 | 16 | 12 |
| 100 | 18 | F | 159 | 76 | 30.1 | OBESE | 3.15 | 2.61 | 83.12 | 76 | 120 | 70 | 1.47 | 16 | 10 |